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INFLUENCE OF AGEING AND VARIOUS TENDERIZATION TECHNIQUES ON THE PALATABILITY AND PROCESSING CHARACTERISTICS OF BISON MEAT

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INFLUENCE OF AGEING AND VARIOUS TENDERIZATION TECHNIQUES ON THE PALATABILITY AND PROCESSING CHARACTERISTICS OF BISON MEAT

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Final Report

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Executive Summary

The specialty livestock meat industry has grown slowly, but steadily. There is a general perception that meat from specialty livestock is less tender, darker in colour and has a strong game flavour compared to that from domestic species. These sensory perceptions surrounding game meat are some of the problems that exist in marketing meat and meat products from specialty livestock species. For three years (from 2000-2003), the Saskatchewan Specialty Livestock Value-Added Program (SLVAP), a program funded by the Saskatchewan Agri-Food Innovation Fund (AFIF) addressed some of these issues. The current project entitled "Influencing of ageing and various tenderization techniques on the palatability and processing characteristics of bison meat", funded by the Saskatchewan Agriculture Development Fund (ADF), was a step forward in the same direction. The project was designed with the following objectives in mind:

1. To standardize and optimize the ageing period for bison meat in order to achieve a tender product.
2. To increase the consistency in tenderness of bison meat, particularly for lesser-value cuts (*i.e.*, chuck and round), by using tenderization methods such as marination (injection and still-marination) and mechanical tenderization (blade tenderization and tumbling), and to make the necessary comparisons with loin counterpart samples.
3. To profile some of the major muscles from the top round to better understand the quality characteristics of these muscles and the extent of variations.

The bison meat industry has come a long way over the past few years, and we consider it to be the major specialty livestock industry in the province. The Saskatchewan Bison Association (SBA) has shown continued interest in research projects being conducted in the Department of Applied Microbiology and Food Science and has contributed generously by sourcing meat samples at various times. Although the SLVAP ended in March 2003, we are still assisting the specialty livestock meat industry in developing

value-added meat and meat products in conjunction with another ADF-funded project entitled "Technical Services for the Saskatchewan Meat Industry."

Research on Objective 1 (*i.e.*, to standardize and optimize the ageing period for bison meat to achieve a tender product) has been detailed in Activity 1. Some of the research for Objective 2 (*i.e.*, to increase the consistency in tenderness of bison meat, particularly for lesser-value cuts (*i.e.*, chuck and round), by using tenderization methods such as marination (injection and still-marination) and mechanical tenderization (blade tenderization and tumbling), and to make the necessary comparisons with loin counterpart samples) has been included/described in Activity 1. Some remaining work for this objective was completed in the last phase of this project, except that instead of top rounds, bottom rounds were characterized (*i.e.*, on account that the SBA could only supply fresh bottom rounds), and is detailed in Activities 3 and 4. The study for Objective 3 (*i.e.*, to profile some of the major muscles from the top round in order to better understand the quality characteristics of these muscles and the extent of variations) has been outlined in Activity 2. Some of the findings from these studies have already been conveyed to the Saskatchewan Bison Association and the Canadian Bison Association and manuscripts for publication are in preparation.

These following activities have been detailed in the following sections:

Activity 1. Optimization of the ageing period for chuck and round: Effects of frozen storage and moisture enhancement on the texture of bison meat.

Activity 2. Muscle profiling of bison top round.

Activity 3. Influence of level of moisture-enhancement and marinade composition on the texture of bison meat.

Activity 4. Optimization of still marination: Effects of still marination and mechanical tenderization on the tenderness and consumer acceptability of bison meat.

Activity 1. Optimization of the ageing period for chuck and round: Effects of frozen storage and moisture enhancement on the texture of bison meat

1. Introduction and objectives

In North America, the Plains bison (*Bison bison bison*) is the primary subspecies used for commercial production of bison meat. In Canada, demand for bison meat is currently increasing faster than its rate of production. There are marked differences in the age, weight, and feeding regimes of animals being slaughtered; this is contributing to the variations in the meat. Inconsistency in the quality of bison meat in the marketplace and utilization of lesser-value cuts are some of the main challenges facing the industry. Only a small portion of the bison carcass, notably the loin and rib, is utilized as "acceptably tender" steaks, while most of the remaining meat is comminuted and used in the production of lesser-value products (*e.g.*, bison burgers), which do not offer a favourable return-on-investment. To meet domestic demand and to launch bison meat into the international arena, further processing is necessary to improve the sensory characteristics of the meat and to increase bison's overall acceptability. Further processing will also aid in increasing the overall carcass value, especially under-utilized or lesser-value cuts (*e.g.*, chuck and round), and thereby provide better financial returns to businesses/individuals within the Saskatchewan bison meat industry. Due to the lack of a federally-inspected slaughter facility in the province and an inconsistent supply of slaughtered animals, most bison meat and products therefrom are marketed in the frozen state. Unfortunately, freezing reduces the quality and functionality of the meat.

Meat quality is a "generic" term used to describe properties and perceptions of meat. The critical point of appraisal of meat quality occurs when the consumer eats the product, and it is this outcome, together with views on colour, healthiness and price, that determines the decision of the consumer to purchase or repurchase (Boleman *et al.*, 1997). The main consumer complaint and the primary cause of failure to repurchase a particular meat product is variability in the eating quality, especially tenderness (Bindon and Jones, 2001; Jeremiah, 1992). Despite efforts to control and optimize animal

production conditions and the pre-slaughter environment, which have a particular impact on tenderness, there is still unacceptable variation in eating quality, suggesting that determinants of meat eating quality are multifactorial and complex (Zamora *et al.*, 2005). In light of this complexity and consumers' concerns about meat quality, attempts to define accurate predictors of meat tenderness have been of great interest for years, but results are not conclusive (Zamora *et al.*, 2005).

As mentioned earlier, meat tenderness is a multifactorial process dependent on a number of biological (*e.g.*, species, sex, age and muscle type) and environmental factors (*e.g.*, nutrition, ante-mortem stress, slaughter and chilling conditions, and ageing). Ageing of meat by holding carcasses or meat at refrigeration temperatures for extended periods after slaughter improves tenderness on account of proteolytic changes in the meat. Current scientific evidence suggests that proteolysis of key myofibrillar and associated proteins is primarily responsible for meat tenderization (Koomhmaraie, 1994; Ouali, 1990). The function of these proteins is to maintain the structural integrity of myofibrils; protein degradation results in weakening of the myofibrils and, consequently, tenderization. As already noted, ageing of meat is done by holding carcasses in a chiller. To save energy costs and chiller space, ageing meat cuts in vacuum packaged bags can be employed. This affords similar positive effects on the tenderness of meat (Kolle, 2004). Ultimate pH of muscle (*i.e.*, pH taken approximately 24 h after slaughter) also has an influence on the tenderness of meat. The normal ultimate pH in meat animals is in the range of 5.5-5.8; higher or lower ultimate pH can adversely affect the quality of meat. For bison meat there is no standard ageing protocol at present being followed by the industry to counteract the deleterious factors affecting tenderness.

The objectives of this activity were to investigate the effects of ageing and frozen storage on the yield and texture of bison chuck and round muscles. The effects of moisture enhancement with sodium chloride and sodium tripolyphosphate on the cooking yield and tenderness of bison meat cuts were also studied.

2. Materials and methods

2.1. Sampling and processing procedures

Fresh bison chucks, top rounds and loins (8 each) were acquired from a federally-inspected facility and trimmed of any visible fat. *Triceps brachii* (TB), *semimembranosus* (SM) and *longissimus lumborum* (LL) muscles were separated from the chuck, round and loin, respectively, and were utilized in this study. Each of these muscles was divided into 3 almost equal portions for a total of 24 pieces from each muscle. The portions were packaged in vacuum bags and aged for 3 different periods (7, 14 and 21 days - 8 each) at 2 different temperatures (4 and –1°C). After ageing, half of these samples were frozen and stored at –30°C for 2, 4 and 6 months to evaluate the effect of freezing on the meat quality. This was necessary because freezing of bison meat is routinely practiced by the industry.

The experiment was repeated. During the second trial, each bison TB, SM and LL (8 each) muscle was divided into 4 almost equal portions for a total of 32 pieces. To compare the ageing and moisture enhancement, the fourth piece obtained from each muscle was injected with brine containing sodium chloride and sodium tripolyphosphate to achieve a 20% extension by weight, while the remaining pieces (24) were aged and processed as aforementioned.

The brine solution used for injection (2±1°C) was formulated to achieve 0.5% sodium chloride and 0.3% sodium tripolyphosphate in the finished marinated product. The sections designated for moisture enhancement were injected using a Fomaco Reiser multi-needle injector (Model FGM20/40, Fomaco Reiser, Burlington, ON, Canada) to a target weight gain of 120% over the raw meat or "green" weight. Re-injection with a hand held injector compensated for any difference in the target weight. Sections were allowed to equilibrate for 5 min following injection to permit draining. The actual injection level attained = (injected weight / raw weight) x 100, was calculated for all marinated muscle sections. During the experiment, all processing was carried out in a refrigerated (8±2°C) pilot plant.

After completion of each conditioning period, muscle samples were sliced, starting from the centre and then moving proximally and distally along the longitudinal plane, so as to obtain 4 one and a half-inch (3.81 cm) thick steaks. These steaks (2 each) were used for evaluation of tenderness after dry- and moist-heat cooking (*i.e.*, cooked to an internal temperature of 72°C). After appropriate storage (*i.e.*, 2, 4 or 6 months), frozen samples were thawed (4°C for 72 h), steaks prepared and then cooked similarly to aged samples for tenderness evaluation.

2.2. *Meat pH analysis*

The pH of each muscle was determined in duplicate by blending 20 g of sample with 80 ml of distilled water for 1 min using an Osterizer Model 548 Blender (Sunbeam Corp., Toronto, ON, Canada). The pH was read using a combination electrode and a Fisher Accumet 915 pH Meter (Fisher Scientific, Nepean, ON).

2.3. *Cooking of steaks and evaluation of tenderness*

2.3.1. *Dry-heat cooking*

Steaks assigned to dry-heat cooking were baked in a conventional oven (Model CRSL3400VM-1, Camco Inc., Moncton, NB, Canada) set at 160°C to an internal temperature of 72°C. Steaks were placed individually on mesh racks in aluminium pans and 2 thermocouples were inserted into the geometric centre of each in order to monitor the internal temperature (See Picture 1.1).

2.3.2. *Moist-heat cooking*

Steaks were wrapped in aluminium foil. Thermocouples were inserted into the geometric centre of each steak and these were cooked at 160°C to the same internal temperature as for dry-heat processed steaks. Before placing steaks in the oven, water (500 ml) was added to the bottom of each pan to generate a moist cooking environment.

The temperatures of the oven and steaks were monitored by thermocouples, which were attached to a scanner (Model 692-8000, Barnant Co., Barrington, IL, USA) and a

computer that recorded the change in temperature at 30-s intervals. Cooking yield = (cooked weight / raw weight) x 100, was recorded for each steak. After cooling to an internal temperature of 50°C, cooked steaks were over-wrapped with Saran® wrap to prevent evaporative loss and held overnight in a 4°C cooler. Then, 6-8 cores (1.27 x 1.27 x 3.81 cm) were removed at random from each steak parallel to the direction of the muscle fibres. Cores were allowed to equilibrate to room temperature for an hour before tenderness measurements (*i.e.*, shear force values) were carried out using a Food Technology Corporation, TMS-TP Texture Press (Rockville, MD, USA), TMS-90 Computer, and a Warner-Bratzler Shear Test Cell with a FTA 3000 Transducer (see Picture 1.2). At the same time when cores for shear force analysis were collected, samples from the centre of each cooked steak and roast were removed so that the expressible moisture could be determined.

2.4. *Expressible moisture*

Expressible moisture (EM) was measured on the same day that the steaks were cooked. Three 1.5-cm cores, avoiding the cooked outer surface, were taken from an 8-mm thick slice of a cooked bison steak. Three of these pieces were weighed and placed in 50-ml centrifuge tubes fitted with thimbles consisting of 2 pieces of Whatman No. 3, 9.0 cm (Whatman International Ltd., Maidstone, England, UK) folded around 1 piece of Whatman No. 50 (5.5 cm) filter paper. The tubes containing samples were stored at 4°C until centrifuged. Centrifugation was carried out for 10 min at 750 x *g* using a Beckman J2-HC with a JS 4.3 Rotor (Beckman Instruments Inc., Fullerton, CA, USA). Meat samples were reweighed after spinning and the percentage of weight lost was reported as EM.

2.5. *Total collagen*

Collagen is the most abundant protein in the animal body (~ 20-25% of total body protein) and can markedly influence meat tenderness. The polypeptide chains of its primary structure each have the repeating sequence of glycine-proline-hydroxyproline- and one additional amino acid. Glycine is the most abundant amino acid in collagen,

whereas hydroxyproline is a relatively constant component of it, and does not occur to any significant extent in other animal proteins. Thus, chemical assays for hydroxyproline are commonly employed to determine the amount of collagen in meat tissues.

Hydroxyproline (990.26) content was determined in bison top round muscle samples according to the AOAC (2000) procedure. Muscle samples (4 g) from TB, LL and SM were hydrolyzed in 30 ml of 3.5 M H_2SO_4 at 105°C for ~16 hours. The hydrolysate was transferred to a 500-ml volumetric flask and diluted to mark with deionised water. An aliquot of this solution was filtered through Whatman No. 40 filter paper. Five millilitres of this filtrate were diluted with deionised water to 100 ml in order to achieve a 0.5-2.4 μg/ml concentration of hydroxyproline in the test solution.

In a test tube, 1 ml of the oxidant solution (Chloramine-T in buffer solution) was added to 2 ml of the test solution. The contents were mixed using a vortex and left to stand at room temperature for 20 min. This step was carried out to convert hydrolyzed hydroxyproline residues to pyrrole. A purple-red chromophore developed when 1 ml of the colour reagent (4-dimethylaminobenzaldehyde in perchloric acid and propanol solution) was added to each test tube. After mixing, tubes were placed in a water bath at 60°C for 15 min for maximal colour development and then cooled under tap water for 3 min. Absorbance measurements were recorded spectrophotometerically at 560 nm using an appropriate blank for background correction.

A calibration curve was prepared using hydroxyproline (*cis*-4-hydroxy-L-proline, Cat. No. H1637, Sigma-Aldrich Canada Ltd., Oakville, ON, Canada) standard solutions containing 0.6, 1.2, 1.8 and 2.4 μg/ml of hydroxyproline, respectively. For colour development the same steps were employed as described for the test sample.

Hydroxyproline content (H) of the test portion was calculated as follows:

$$H \text{ (g / 100 g of raw meat)} = (h \times 25)/(m \times v),$$

where h = hydroxyproline content, µg/2 ml filtrate, read from the calibration curve;

m = mass (g) of the test portion; v = volume (ml) of filtrate taken for dilution to 100 ml from the hydrolysis step.

The collagenous connective tissue content (B) of the test sample was calculated as follows:

B (g / 100 g) = H x 8 (collagenous connective tissue contains 12.5% hydroxyproline, if a nitrogen-to-protein factor 6.25 is used).

2.6. *Statistical Analysis*

The effects of muscle type (3; TB, SM and LL), ageing period (3; 1, 2 and 3 weeks), ageing temperature (2; -1 and +4°C) and cooking method (2; dry- and moist-heat) on processing parameters and palatability estimates of bison meat were analyzed using the General Linear Model (GLM) procedures of the SPSS statistical package (SPSS, 1999). For the second half of the experiment, effects of muscle type (3; TB, SM and LL), moisture enhancement (2; control and moisture enhanced) and cooking method (2; dry- and moist-heat) on cooking yield and texture were analyzed. For tabulation purposes, data are pooled across main effects; *e.g.*, while comparing muscles for shear force values, data are pooled across ageing periods, ageing temperatures and cooking methods as indicated in Table 1.1. Least-squares means (LSM) and standard errors of the mean (SEM) for all parameters used in the study were computed and tested for differences between treatments. Significance levels between the treatments for a particular parameter were assessed at $P<0.05$ as stated in the results.

3. Results and discussion

For this study muscles from the chuck and round were used. The muscles from these cuts of bison were selected because chuck and round are less tender and under-utilized, and are considered of lesser value compared to loin, which is the tenderest cut of meat in a carcass. Further processing of these cuts would help increase the overall value of the carcass; consequently, better financial returns for the producers and processors.

Therefore, the ageing period and holding temperature of muscles from the top round (SM) and chuck (TB) were optimized and data were compared against those for the loin (LL).

3.1. Relationship between ultimate pH on tenderness

After slaughter, improvement in meat tenderness occurs gradually (Devine, 2004; Kolle *et al.*, 2004). During this post-mortem or ageing period, tenderization results from protein degradation/proteolysis. The proteolytic processes originate within the myofibre and various proteolytic enzymes such as cathepsins and calpains are responsible for degradation of cellular constituents (Koohmaraie, 1994). Activities of these enzymes are influenced by a number of factors of which pH is one of the main determinants; *e.g.*, for calpains, a pH of 6.6-6.8 is required for their optimal activity. The pH drops to 5.4-5.6 (also known as ultimate pH) owing to glycolytic activity in the meat following slaughter. Stress before slaughter can also affect the quality of meat, including its tenderness. Better handling of animals during transport and providing them with adequate rest before slaughter are very important. Stress of any kind leads to some biochemical changes in muscles causing the pH of the meat to rise above normal limits after slaughter. Ultimately, this deteriorates meat quality. Meat from stressed animals is darker, dry and less tender than stress-free animals and is not liked by consumers. In the present study, the initial pH was in the range of 5.5-5.6 with no significant differences between any of these muscles.

3.2. Tenderness variability and relationship between collagen and tenderness

The initial tenderness of meat, before significant ageing has taken place, is not consistent: it varies from one muscle to another, among individuals of the same species and for different species. The total amount of connective tissue within muscles of the same animal affects tenderness between muscles. The content of connective tissue, mainly collagen, in muscles is probably a reflection of the functional demands during the animal's life; *e.g.*, the muscles from the round are used for locomotion and consequently are higher in connective tissue and less tender than muscles from the loin, which are

mainly used for structural support. With ageing, the chemical structure of connective tissue components in muscles changes and becomes more tightly bound leading to a reduction in meat tenderness. Owing to more physical activity, game animals tend to have more connective tissue in their muscles compared to domestic ones.

After slaughter, one of the most important changes that occur during the conversion of muscle to meat is stiffening of muscles after death, known as rigor mortis. Ageing is considered to begin at the moment that rigor mortis is complete. Depending on the initial glycogen level, each individual muscle fibre enters rigor at different points. Consequently, ageing commences at different times in the various muscle fibres. The degree of tenderness of muscles is determined partially by the post-rigor contraction state, a condition controlled in part by the amount of tension on muscles during rigor onset. The tenderness of unaged meat and the extent of ageing that takes place on completion also depend on factors such as muscle shortening. Highly shortened meat does not tenderize effectively, so that, in the case of severe cold shortening – a worst-case scenario – the meat is extremely tough and appears not to have aged at all (Devine, 2004).

As expected, before any processing there was variation in tenderness between the muscles examined in this study. LL had significantly ($P<0.05$) lower shear force values (more tender) than SM and TB, whereas SM and TB did not differ significantly ($P>0.05$) in tenderness (Table 1.1). In fact, TB and SM muscles exhibited greater average shear force values of 19.7 and 16.7% than that for LL. There was no significant difference ($P>0.05$) in the total collagen contents of these muscles; however, collagen contents correlated with the shear force values so obtained.

3.3. *Effects of duration of ageing on tenderness*

In general, meat ages as it moves along the distribution system from slaughter to the consumer, but the optimal tenderness will not be reached unless the duration of ageing is sufficient to cause protein degradation/proteolysis (Koohmaraie, 1988). Generally, it takes *ca.* 14-21 days of ageing/conditioning to achieve a desirable texture in beef

(Morgan, 2003). We assumed bison meat would require the same period of ageing as beef in order to achieve optimum tenderness, that's why an ageing period of 3 weeks was selected for this study. We expected significant improvement in tenderness after 1 and 2 weeks but found that contrary to the general perception, bison does not behave in the same manner as beef. This is a very important conclusion we reached from our study, and it will have a significant impact on the Saskatchewan bison meat industry. One can not simply assume that the standards/protocols employed in the processing of beef are applicable to bison meat.

After 2 weeks of ageing in vacuum bags, there was no significant ($P>0.05$) effect on yield and texture of the 3 muscles studied; however, after the third week, muscles were significantly ($P<0.05$) more tender compared to those aged for 1 and 2 weeks (Table 1.1). After 3 weeks, there was about a 15% improvement in tenderness compared to day 0 and around 8-10% compared to weeks 1 and 2. As evident in Figure 1.1, texture of all 3 muscles was significantly improved after 3 weeks of ageing, but this effect was more pronounced in LL than SM and TB muscles. As mentioned earlier, in this study a maximum ageing period of 3 weeks was selected, which is a standard for most other red meats. It will be interesting to see the effect of a prolonged ageing period (*i.e.*, 4-6 weeks) on bison meat quality in future research endeavours.

3.4. Effects of temperature on ageing

Ageing temperature can influence the quality of meat. In a typical meat-processing plant, the muscle temperature of a harvested carcass falls, depending upon the exact chilling regimen, and the rate of ageing is gradually reduced throughout processing until a stable storage temperature is reached. The ageing rate of meat increases dramatically as the temperature rises and, for a 10°C temperature rise, the rate increases 2.4 times (Davey and Gilbert, 1976). Higher temperature conditioning can facilitate bacterial spoilage; that is why low temperatures for beef ageing are recommended along with suitable packaging; *i.e.*, vacuum packaging (Davey and Gilbert, 1976). Ageing of meat from game animals under vacuum packaging makes even more sense as carcasses obtained from these animals have very thin

subcutaneous fat cover, which can make the meat susceptible to moisture loss, thereby resulting in an adverse effect on meat quality.

In this study, the conditioning temperature used were +4 and –1°C, which are lower than the standard ageing temperatures employed by industry. This could be a reason why we did not observe any significant (P>0.05) effect of ageing temperature on the tenderness of the 3 types of bison muscles studied. Nevertheless, cooking yields were improved for muscles stored at –1 than those aged at +4°C. Although there was no significant effect of temperature, as mentioned earlier, ageing meat at a reduced temperature helps to ensure that low levels of pathogenic and spoilage bacteria are maintained. This is especially important if longer ageing periods are to be employed.

3.5. *Effects of moisture-enhancement and cooking method on meat texture*

From our previous studies, we found that moisture enhancement with a brine solution containing 0.5% NaCl and 0.3% STPP significantly (P<0.05) improved the cooking yield and texture of bison meat (Dhanda *et al.*, 2002, 2003). That's why the same brine composition was used for the second half of the experiment: the effect of moisture enhancement on the yield and texture of SM, TB and LL muscles was assessed (Figure 1.3 and Table 1.3). The aim of this study was to compare the positive effects of moisture-enhancement/marination with that of ageing. There was significant (P<0.05) improvement in the tenderness of steaks from all 3 muscles; however, reduction in shear force values was more evident in SM and TB than LL muscle. From this experiment, it was also clear that similar to ageing, moisture enhancement could equally reduce the shear force values of meat, if keeping the muscles intact is not an issue.

Moist-heat cooking and marination significantly (P<0.05) decreased the cooking losses and increased the tenderness of steaks obtained from SM, TB and LL muscles. The selection of cooking method depends upon the type of cut and the amount of connective tissue in the meat. Dry- and moist-heat methods are mainly employed for cooking meat and meat products. Conventional dry-heat cooking results in less-tender meat from high connective tissue cuts such as the chuck and round compared to cuts with lower

connective tissue contents such as the loin. It is desirable to provide extra water during cooking to help facilitate the complete hydrolysis of collagen. We observed that moist-heat cooking resulted in lower cooking losses and shear values when cooking top round steaks and roasts compared to that by dry-heat (Dhanda *et al.*, 2002, 2003). Similar findings were observed in the present study. Along with moist-heat cooking, moisture enhancement of bison meat before thermal processing can further increase the palatability of these less tender meat cuts by increasing the cooking yield and tenderness.

3.6. Effects of freezing on meat texture

After ageing, half of the muscle samples from SM and TB were stored at –30°C for 2, 4 and 6 months to evaluate the effect of freezing on meat texture. This was done to mimic the practice followed by the meat industry. As aforementioned, most meat from bison, especially lesser-value cuts, is marketed in the frozen state. LL, being a high-priced and tender muscle, is generally sold fresh; therefore, it was not used in the freezing experiments. Data from this part of the study are presented in Table 1.2. There was a significant ($P<0.05$) reduction in cooking yield (~ 10%) and tenderness (~ 15%) of these muscle samples after frozen storage compared to aged fresh samples, although there was no difference between the different periods of frozen storage (*i.e.*, 2, 4 and 6 months; Figure 1.2). This finding supports the fact that frozen storage has an adverse effect on meat quality.

4. Conclusions and recommendations

Ageing can significantly improve the tenderness of bison *semimembranosus*, *triceps brachii* and *longissimus lumborum* muscles; however, a minimum of a 3 weeks' period is necessary to achieve the desired results. Freezing has a detrimental effect on meat quality, so it should be used only in unavoidable circumstances. The results from these experiments emphasize the need for moisture enhancement and moist-heat cooking of less-tender cuts. These findings have been communicated to the Saskatchewan Bison

Association and the Canadian Bison Association; a manuscript from the results of this research is in preparation.

From the results obtained of the aforementioned experiments, it is clear that marination has a positive effect on the palatability of lesser-value cuts; however, it took a long time to age the bison meat to achieve a significant effect on tenderness, so strategies are needed to minimize the ageing period and to make meat more tender in the process. To decrease this inconsistency a different approach of post-mortem intervention (e.g., manipulation of the proteolytic activities) is needed to increase the consistency in the quality of bison meat cuts, especially those of lesser value. After slaughter, improvement in meat tenderness occurs gradually. As already noted, during this post-mortem or ageing period, tenderization results from protein degradation/proteolysis. The proteolytic processes originate within the myofibre and are responsible for degradation of cellular constituents (Koohmaraie, 1988). The subject of proteolytic enzymes in post-mortem muscle has received some attention: the proteolytic enzymes in meat which have been most studied are the cathepsins and calpains (Faustman, 1994). While the role of cathepsins has been controversial and hotly debated, the calpains are considered to play an important role in post-mortem tenderization of meat (Koohmaraie, 1994). The calpain system consists of μ-calpain and m-calpain (*i.e.*, also known as calcium-dependent proteases) and their specific inhibitor known as calpastatin (Ouali, 1990). For the past two decades, peptidase inhibitors have often been viewed as better predictors of meat texture than their target enzymes (Sentandreu *et al.*, 2002). Apart from calpastatin, a specific inhibitor of the ubiquitous calpains, little is known concerning the other peptidase inhibitors, which can be isolated from skeletal muscle tissue (Ouali *et al.*, 1995). In a recent study, Zamora *et al.* (2005) concluded that serine peptidases and their inhibitors are best predictors of beef ageing amongst a large set of quantitative variables. This work opens new pathways to explore the mechanisms involved in the post-mortem tenderizing process. It is recommended that these new findings be explored to find ways to explain the ageing process of bison meat.

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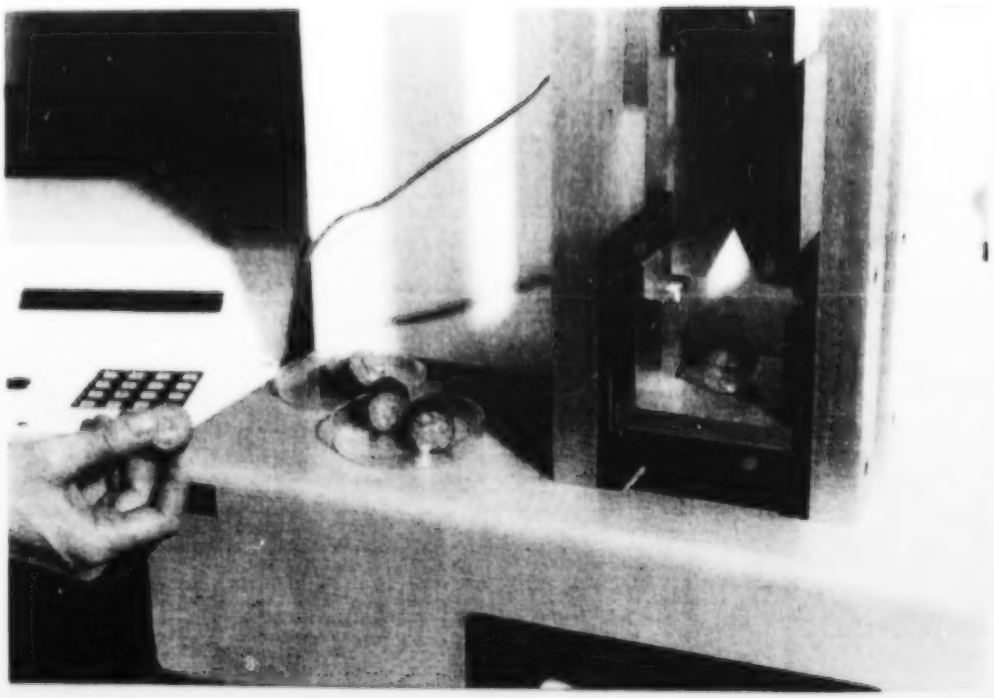
Picture 1.1. **Image depicting dry-heat cooking of steaks in a conventional oven and monitoring of the steaks' internal temperature using thermocouples attached to a scanner and computer.**



Picture 1.2. Texture press machine depicting a Warner-Bratzler shear cell.

Table 1.1
Effects of muscle type, ageing period, ageing temperature and cooking method on the yield, shear force and collagen content of bison meat

Item	Cooking yield (%)	Shear force values (N)[x]	Total collagen (g/100g)
Muscle type			
Triceps brachii (TB)	74.6a	86.8a	1.68a
Longissimus lumborum (LL)	74.4a	69.7b	1.52a
Semimembranosus (SM)	75.2a	83.7a	1.57a
S.E.M.[y]	0.62	1.30	0.07
Ageing period			
One week	76.5a	83.2a	1.65a
Two weeks	74.3ab	80.1a	1.59a
Three weeks	72.7b	72.9b	1.54a
S.E.M.[y]	0.72	1.50	.06
Ageing temperature			
-1°C	75.8a	78.9a	1.56a
+4°C	73.2b	81.2a	1.62a
S.E.M.[y]	0.58	1.23	0.05
Cooking method			
Dry-heat	71.9b	81.8a	1.65a
Moist-heat	77.1a	75.3b	1.53a
S.E.M.[y]	0.58	1.23	0.04

Data are pooled across main effects; *e.g.*, when comparing muscles for a particular parameter, data from ageing periods, ageing temperatures and cooking methods are pooled.
a-b, Means with different letters in the same column (within each main effect) are significantly ($P<0.05$) different.
[x]SFV, shear force value (N = Newton, SI unit of force), a Newton can be converted into kg force by dividing the N value by 9.80665.
[y]S.E.M, Standard error of the mean.

Table 1.2
Effects of muscle type, freezing period and cooking method on the yield and shear force of bison meat

Item	Cooking yield (%)	Shear force values (N)[x]
Muscle type		
Triceps brachii (TB)	68.5a	89.7a
Semimembranosus (SM)	66.2a	92.2a
S.E.M.[y]	0.62	2.04
Freezing period		
Two months	66.6a	92.5a
Four months	66.8a	91.3a
Six months	68.7a	89.0a
S.E.M.[y]	0.76	2.51
Cooking method		
Dry-heat	65.5b	95.1a
Moist-heat	69.2a	86.8b
S.E.M.[y]	0.62	2.04

Data are pooled across main effects; *e.g.*, when comparing muscles for a particular parameter, data from freezing periods and cooking methods are pooled.
a-b, Means with different letters in the same column (within each main effect) are significantly ($P<0.05$) different.
[x]SFV, shear force value (N = Newton, SI unit of force), a Newton can be converted into kg force by dividing the N value by 9.80665.
[y]S.E.M, Standard error of the mean.

Table 1.3
Effects of interactions of muscle type, moisture enhancement and cooking method on the yield and shear force of bison meat

Interactions		Cooking yield (%)	Shear force values (N)[x]
*Muscle*moisture enhancement*			
Triceps brachii (TB)	Control	79.7b	87.2a
	Enhanced	83.0a	76.0b
Longissimus lumborum (LL)	Control	76.2a	68.8a
	Enhanced	78.5a	65.1b
Semimembranosus (SM)	Control	79.5b	86.2a
	Enhanced	83.9a	72.4b
S.E.M.[y]		1.55	1.34
*Muscle*cooking method*			
Triceps brachii (TB)	Dry-heat	78.4b	87.3a
	Moist-heat	84.2a	75.9b
Longissimus lumborum (LL)	Dry-heat	77.0a	69.2a
	Moist-heat	77.6a	64.8b
Semimembranosus (SM)	Dry-heat	79.5b	82.6a
	Moist-heat	83.8a	76.1b
S.E.M.[y]		1.55	1.34
*Moisture enhancement*cooking method*			
Control	Dry-heat	75.6b	86.3a
	Moist-heat	79.6a	79.2b
Enhanced	Dry-heat	79.8b	73.1a
	Moist-heat	85.5a	65.3b
S.E.M.[y]		1.36	1.18

Data are pooled across main effects; *e.g.*, when comparing muscles for a particular parameter, data from moisture-enhancement and cooking methods are pooled.
a-b, Means with different letters in the same column (within each interaction group) are significantly ($P<0.05$) different.
[x]SFV, shear force value (N = Newton, SI unit of force), a Newton can be converted into kg force by dividing the N value by 9.80665.
[y]S.E.M, Standard error of the mean.

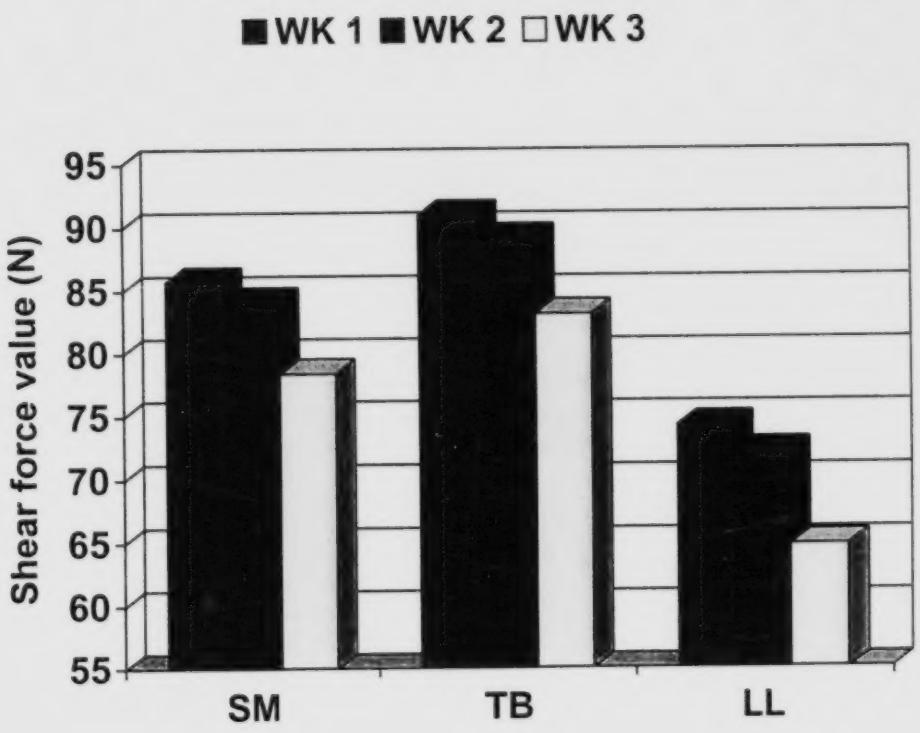


Figure 1.1. **Effect of ageing period on the shear force values (N) of bison *semimembranosus* (SM), *triceps brachii* (TB) and *longissimus lumborum* (LL) muscles.**

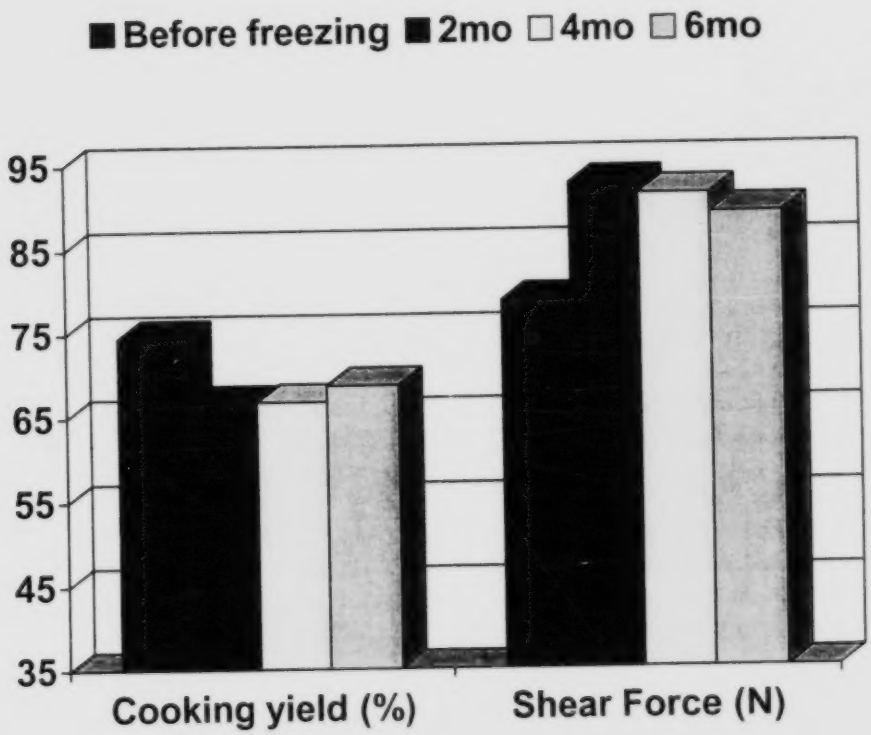


Figure 1.2. **Effect of freezing on cooking yield and shear force values (N) of bison meat.**

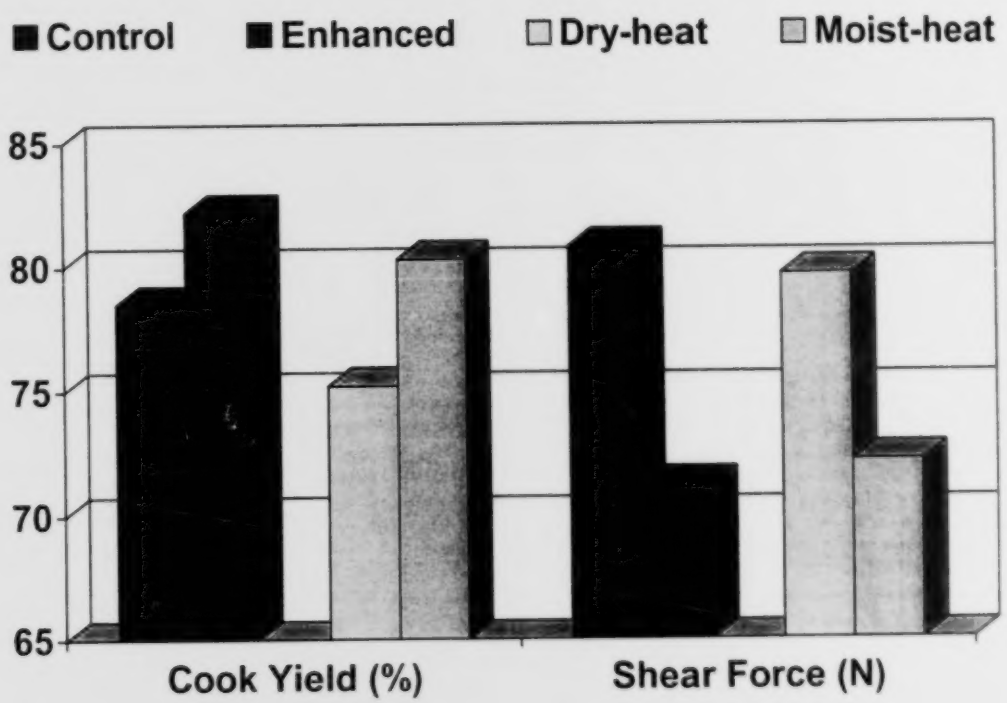


Figure 1.3. **Effect of moisture enhancement and cooking method on the cooking yield (%) and shear force values (N) of bison meat.**

Activity 2. Muscle profiling of bison top round

1. Introduction and objectives

There exist large variations in the quality characteristics (*i.e.*, colour, tenderness, juiciness and flavour) of meat available from an animal carcass, between different primal cuts recovered from it and even among muscles within a specific cut. Important processing parameters such as meat colour and cooking loss can be affected by these variations in the different muscles. Factors responsible for causing these changes include ante-mortem (*e.g.*, heredity, age, sex, diet, muscle location and stress) and post-mortem factors (*e.g.*, chilling time and temperature, ultimate pH). Muscle profiling studies are very helpful to control and improve the quality of meat. A detailed study on profiling beef muscles had been carried out by Von Seggern *et al.* (2005). To our knowledge, no such scientific study on bison meat is available in the literature to date. The purpose of this exercise was to characterize some of the muscles in bison round to find optimal uses of each muscle, thereby ensuring better financial returns for Saskatchewan processors. It is our intention that such knowledge would be used by the bison industry. In this study, some of the major muscles from the bison top round were profiled for various indicators of meat quality (*e.g.*, colour, pH, expressible moisture, tenderness) and proximate chemical composition (*i.e.*, moisture, crude protein, fat, ash and collagen). Top round is a lesser-value cut and quite commonly used for further processing; that is why we opted to profile muscles from this cut.

From the hip of bison carcasses 3 main cuts can be obtained: Sirloin tip (knuckle), top or inside round and the bottom or outside round. Figure 2.1 illustrates the various muscles of the top and bottom round of bison. The top round consists of 5 muscles, namely *semimembranosus* (SM), *adductor* (ADD), *gracilis* (GRA), *pectineus* (PEC) and *sartorius* (SR). While separating these muscles from the top round, the following order is generally followed: first SR is removed followed by PEC and GRA, and then ADD is removed from the remaining SM muscle. The ADD muscle is a thick triangular muscle which lies between the SM and the femur bone; GR is a flat muscle which lies directly

over the SM and ADD muscles; PEC is a small cone-shaped muscle that lies adjacent to the ADD muscle; SR is a thin narrow muscle which is adjacent to GRA; and SM is the largest of all and lies beneath the GRA muscle. For this study, the 4 major muscles of the top round, namely SM, ADD, GRA and PEC, were examined. The SR muscle was too small to obtain a sufficient number of samples for all the parameters investigated; therefore, it was not profiled in this study. In total, data from 22 animals were collected to make a fair assessment of the parameters examined.

2. Materials and methods

2.1. *Sampling and processing procedures*

The animals used for this study were intact males. The carcasses obtained from these animals ranged from grade A1 to B1. Top rounds from these carcasses were purchased from Bouvery Exports Calgary Ltd., Calgary, AB, 4 days after slaughter. As mentioned above, 4 major muscles of the top round – SM, ADD, GRA and PEC – were separated for this study and assessed for various indicators of meat quality (*i.e.*, colour, pH, expressible moisture, tenderness – after dry and moist heat cooking) and proximate chemical composition (*i.e.*, moisture, crude protein, fat, ash as well as collagen). Muscle samples were sliced to obtain 4 x 3.81 cm thick steaks (2 each were used for evaluation of tenderness after dry- and moist-heat cooking) and 1 x 1.27 cm steak (used for colour appraisal). One top round was investigated every other week. For the study, all processing was carried out in a refrigerated (8±2°C) pilot plant. Muscle samples for proximate composition analysis, total pigment estimation and collagen determination were collected at the time of processing and stored at –30°C until they could be analyzed.

2.2. *Colour appraisal*

From fresh muscles, 1.27 cm thick steaks were prepared as described earlier. These freshly cut steaks were placed on Styrofoam trays without wrapping in the refrigerated pilot plant for 45 min to bloom. After this period, the steaks on each tray were over-

wrapped with an oxygen permeable film (30,000 $cm^3/m^2/24h$; Vitafilm, Huntsman Film Products of Canada, Toronto, ON, Canada). Colour was then determined using a Hunterlab Miniscan XE (Hunter, Reston, VA, USA) colorimeter, which was set at L*, a* and b*, observer 10 and illuminant A. Two readings of Hunter colour values were recorded at right angle to each other at the same position marked on each steak. Hue angle ($\tan^{-1}$ b*/a*) and chroma or saturation $[(a^{*2} + b^{*2})^{1/2}]$ were calculated as described by Wyszecki and Stiles (1982).

2.3. *Muscle pigment concentration*

The muscle pigment concentration of previously frozen bison meat samples was analyzed as per Warriss (1979). Briefly, meat pigments were extracted from minced muscle samples (5 g) with 25 ml of ice-cold 0.04 M phosphate buffer (pH 6.8) for 20 s using a Polytron homogenizer with a PTA-10S generator (Brinkmann Instruments [Canada] Ltd., Mississauga, ON, Canada). After standing for 1 h at 4°C, the homogenates were centrifuged at 6500 x *g* for 10 min. A few crystals of potassium ferricyanide and sodium cyanide were added to the supernatants to convert the extracted meat pigments to their cyanmet forms. The tubes were again centrifuged at 30,000 x *g* at 15°C for 1 h. Absorbances were then read at 540 nm using an appropriate blank for background correction. Total pigment concentrations were calculated by multiplying the absorbances by 1.45: a factor derived from the extinction coefficient of cyanmet myoglobin, and a dilution factor based on the moisture content of meat being 75%.

2.4. *Proximate chemical composition analysis*

The proximate chemical composition, *i.e.*, moisture (950.46, AOAC, 1990), crude protein (981.10, AOAC, 1990), fat (960.39, AOAC, 1990) and ash (920.153, AOAC, 1990) of muscle samples was determined. Crude protein was determined by using a conversion factor of 6.25.

2.5. *Cooking of steaks and evaluation of tenderness*

Steaks were cooked using dry- and moist-heat methods to an internal temperature of 72°C. The cooking methods employed and tenderness evaluation carried out were those described in Activity 1.

2.6. *Total collagen, pH and expressible moisture (EM)*

These parameters were analyzed as described in Activity 1.

2.7. *Statistical Analysis*

The effects of muscle type (4; *adductor* [ADD], *gracilis* [GRA], *pectineus* [PEC] and *semimembranosus* [SM]) and cooking method (2; dry- and moist-heat) on cooking yield and texture were analyzed, while the effect of muscle type was assessed on colour and proximate composition of bison meat using the General Linear Model (GLM) procedures of the SPSS statistical package (SPSS, 1999). Least-squares means (LSM) and standard errors of the mean (SEM) for all parameters used in the study were computed and tested for differences between treatments. Significance levels between the treatments for a particular parameter were assessed at $P<0.05$, as stated in the results.

3. Results and discussion

Top round muscles from 22 animals were profiled for this study. Average weights of ADD, GRA, PEC and SM muscles are tabulated in Table 2.1, and the proportions of various muscles in the top round are depicted in the Figure 2.2. More than half of the top round is comprised of SM muscle (55%), ADD makes up ~ 19%, GRA and PEC muscles contribute ~ 12% each, whereas SR muscle is the smallest and the negligible proportion of the top round. To show visual differences, digital images of these muscles were taken and have been included in this report.

3.1. *Meat colour*

Meat colour is an important determinant of the eye appeal of meat. The reference system of colour measurement on a cut meat surface is specified in the CIE (Commission International de l' Eclairage) colour space (Swatland, 1995). Any colour may be matched exactly by a suitable mixture of the 3 primary colours (red, blue and green) and the relative amounts required match a given colour are known as tristimulus values (Price and Schweigert, 1987). The CIE – L*, a*, b* space is a visual uniform transformation of the CIE tristimulus values and is used in units of L* (lightness), a* (redness/greenness) and b* (yellowness/blueness), also known as Hunter Lab values (Warner, 1989).

Hunter Lab colour values, particularly a* values, are a good indication of the redness of meat: the greater (positive) the a* value, the redder the meat. Concentration and chemical state of haem pigments (*i.e.*, myoglobin, haemoglobin and cytochrome C) are responsible for the colour of fresh meat. In well-bled muscle tissue, myoglobin constitutes 80-90% of the total meat pigment. The quantity of myoglobin in meat varies with species, age, sex, muscle and physical activity. Species differences are obvious. For example, compare freshly ground beef, which is bright red in colour to that of pork, which is pinkish. With the advancement of age, the myoglobin content increases making meat from mature animals darker compared to young ones. The muscles from male animals contain more myoglobin than those of females or castrates. Furthermore, different muscles in the body have varying myoglobin contents. For example in chicken, this is why breast muscles are lighter in colour than leg muscles. Game animals have darker-coloured muscles than domestic animals partially because of a high myoglobin content that is induced in muscles from physical activity. Similar to the observation made during previous studies, bison top round muscle samples appeared dark red. The negligible amount of intramuscular fat (1.6-2.1%) may also contribute to its darker appearance.

The surface colour of meat develops after the meat has been cut and exposed to air. This process called "blooming" involves the conversion of myoglobin to oxymyoglobin in the presence of oxygen and usually requires at least 15 min to develop on a meat

surface (Kryzwicki, 1979). In our previous study on bison meat, we found that a time of 45 min was needed for optimum bloom to develop (Dhanda *et al.*, 2002).

Of the 4 muscles studied, ADD and SM were significantly ($P<0.05$) redder (higher a* values) than GRA, whereas a* values of PEC and GRA did not differ significantly ($P>0.05$) (Table 2.2). The fact that GRA and PEC muscles were less red was likely due to the difference in the amount of total haem pigment between these muscles. This was investigated and haem content data revealed that GRA and PEC muscles contained significantly lower pigment concentrations than ADD and SM counterparts. This observation was also supported by the chromacity and hue angle values obtained from Hunter data reduction. Higher contents of intramuscular fat in GRA and PEC than ADD and SM can also contribute to the lighter colour of these muscles, although the differences were not significant ($P>0.05$). In the present study, total pigment concentration for bison meat was in the range of 7.2 to 9.1 mg myoglobin equivalent/g of wet tissue compared to 1.8, 5.0 and 5.1 mg/g reported for pork, mutton and beef, respectively (Warriss, 1979). This fact supports the previous statements about greater myoglobin content of game animals owing to their higher physical activity compared to domestic species.

3.2. *Proximate composition*

All the top round muscles were similar ($P>0.05$) in terms of their proximate composition with 21-22% crude protein, 1.6-2.1% fat and 1.1-1.3% mineral contents (Table 2.3). The only variation noted was the moisture content of these muscles. PEC muscle had ~ 76% moisture compared to ~ 74% for ADD, GRA and SM muscles. In a muscle profiling study by the National Cattlemen's Beef Association, crude protein contents of 19-21% were reported for ADD, GRA, PEC and SM muscles of beef, which are similar to those reported for these muscles for bison in the present study; however, bison muscle samples were markedly leaner (fat contents of 1.6-2.1%) compared to beef muscles (fat contents of 3.1-4.6%).

3.3. *Texture and its relationship with cooking methods*

There were significant ($P<0.05$) differences in the cooking yield and shear force values (tenderness) of the 4 top round muscles. On combining the data across cooking methods, GRA and SM had significantly ($P<0.05$) higher shear force values, thus were less tender compared to ADD and PEC (Table 2.4). PEC had significantly higher cooking yields compared to SM, whereas ADD, GRA and SM did not differ significantly ($P>0.05$). Higher cooking yields of ADD and PEC may be attributed to their higher pH (Table 2.3) and better moisture retention (higher expressible moisture) compared to GRA and SM; whereas tenderness variations could be contributed to differences in cooking loss and collagen content between these muscles. Collagen contents of ADD, GRA, PEC and SM muscles were 1.52, 1.64, 1.54 and 1.72 g hydroxyproline equivalent/100g of wet tissue, respectively.

In the present study, the recorded mean shear force values for muscles examined were in the range of 74-77N, which are very low (38-48N) compared to those reported by Von Seggern *et al.* (2005) and NCBA (2000) for the same muscles from beef carcasses. It is difficult to compare absolute shear force values amongst published studies because of variations between animals (*i.e.*, different genotype, feeding regimes, age and gender) and different sampling, cooking and measurement techniques

Steaks from these 4 muscles were cooked by dry- and moist-heat methods. As observed in the previous studies on bison meat, moist-heat cooking is a better option for a cut such as top round (Dhanda *et al.*, 2002). Due to higher moisture retention, moist-heat cooking steaks result in higher cooking yield and a tenderer product than dry-heat cooking. These previous observations were supported by the findings of the present study (Table 2.5). Myofibrillar and connective tissue proteins (mainly collagen) are responsible for major textural changes in meat during thermal processing. Two broad categories of cooking meat; *i.e.*, dry- and moist-heat cooking methods, have different effects on the meat texture depending on the muscle cut used. The overall palatability of meat cooked by dry-heat methods (*e.g.*, baking, broiling and roasting) is influenced to a large extent by the degree of doneness. Cooking losses are increased as the cooking temperature and end-point temperature increase. Consequently, this leads to a

decrease in juiciness, high cooking losses along with protein hardening and toughening induced by high cooking temperatures, which markedly reduce tenderness. Meat cooks so rapidly at these high temperatures that the cooking time is not long enough to allow a sufficient amount of collagen solubilization to take place thereby ensuring acceptable tenderness. This is why cooking by dry-heat is appropriate for tender cuts with a low connective tissue content (*e.g.*, steaks and roasts from ribs, short loins and sirloins). On the other hand, conventional dry-heat cooking results in less tender meat from high connective tissue cuts (*e.g.*, shank, brisket, chuck and round cuts) than from low-connective tissue cuts. If meat contains a high amount of connective tissue, moist-heat cooking (*e.g.*, braising, pot roasting and steam-cooking) is recommended. It is therefore, desirable to provide extra water during cooking for the complete hydrolysis of collagen.

4. Conclusions and recommendations

Bison *adductor* and *pectineus* muscles were lighter in colour and more tender than the *gracilis* and *semimembranosus* muscles from the top round. Moist-heat cooking is the desired method of thermal processing for all of the top round muscles of bison investigated in the present study. Bison top round muscles were similar in terms of protein content (~ 21%) but were markedly leaner to those from beef.

Physical and chemical characteristics of individual muscles within a cut can influence the overall palatability and processing suitability of that cut. To maximize benefits, processors could employ muscle-based processing, especially for lesser-value meat cuts. The data acquired from the characterization of different top round muscles of bison might be useful for this purpose. Activity 2 of this report is a first step towards the preparation of a muscle-profiling guide for bison meat. To complete the story, however, it is recommended that additional muscles of other lesser-value cuts, such as the bottom round and chuck, be characterized. All data can then be compiled to create a processing guide for the Saskatchewan bison meat industry.

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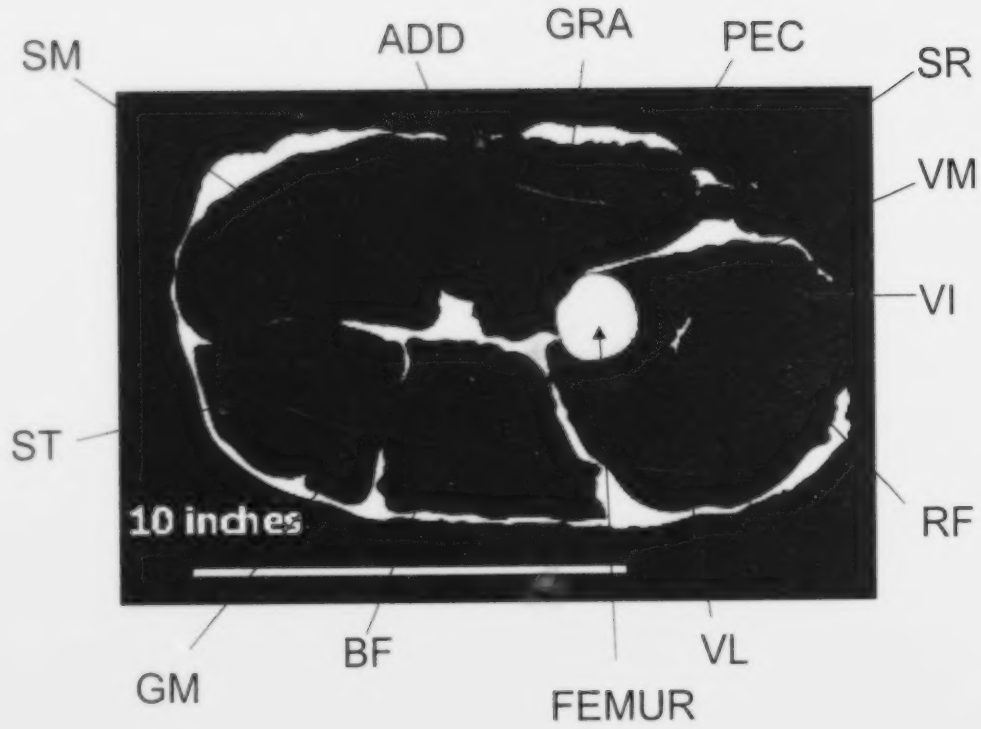


Figure 2.1. A diagrammatic representation of the cross section of bison round. Rounds consist of the top or inside and bottom or outside round. Top round includes *semimembranosus* (SM), *adductor* (ADD), *gracilis* (GRA), *pectineus* (PEC) and *sartorius* (SR) muscles while the bottom round is comprised of the *quadriceps* group [*vastus medialis* (VM), *vastus intermedius* (VI), *rectus femoris* (RF) and *vastus lateralis* (VL)], *biceps femoris* (BF), *gluteus medius* (GM) and *semimtendinosus* (ST) muscles.

Table 2.1
Average weight (±S.D.) of four major muscles from the bison top round

Muscle	Weight (g)
adductor (ADD)	1471 ± 166
gracilis (GRA)	944 ± 64
pectineus (PEC)	914 ± 57
sartorius (SR)	62 ± 5.2
semimembranosus (SM)	4203 ± 141
Top round	**7595 ± 242**

Figure 2.2. Proportion of various muscles in the top round: *adductor* (ADD), *gracilis* (GRA), *pectineus* (PEC), *sartorius* (SR) and *semimembranosus* (SM).

Table 2.2
Hunter Lab values, meat pigment concentration and collagen content of four muscles from the bison top round

Muscle	Hunter Lab values			Hue angle[x]	*Chroma*[x]	Total pigment (mg/g)[y]	Total Collagen (g/100g)
	L*	a*	b*				
adductor (ADD)	36.0a	30.2a	22.3a	36.4a	37.6a	9.05a	1.52b
gracilis (GRA)	34.4a	26.6c	16.7b	32.0b	31.4b	7.23b	1.64a
pectineus (PEC)	35.2a	27.4bc	17.9b	33.1b	32.8b	7.71b	1.54b
semimembranosus (SM)	34.8a	29.2ab	21.7a	36.6a	36.4a	8.93a	1.72a
S.E.M.[z]	0.98	0.77	0.81	0.71	1.03	0.52	0.04

a-b, Means with different letters in the same column are significantly ($P<0.05$) different.
[x]Hue angle ($\tan^{-1}$ b*/a*) and chroma or saturation [$(a^{*2} + b^{*2})^{1/2}$] were calculated from Hunter Lab values.
[y]Total pigment concentration is expressed in mg of myoglobin equivalent/g of wet tissue.
[z]S.E.M, Standard error of the mean.

Table 2.3
Proximate composition and pH of four muscles from the bison top round

Muscle	Proximate composition (%)					
	pH	Moisture	Protein	Fat	Ash	Carbohydrate[x]
adductor (ADD)	5.60a	74.3b	21.1 a	1.7a	1.31a	1.07a
gracilis (GRA)	5.53ab	74.5b	21.2a	2.1a	1.26a	0.99a
pectineus (PEC)	5.59a	75.6a	20.8a	1.9a	1.17a	0.77a
semimembranosus (SM)	5.49b	74.5b	21.6a	1.6a	1.18a	1.14a
S.E.M.[y]	0.11	0.28	0.33	0.22	0.05	0.21

a-b, Means with different letters in the same column (within each main effect) are significantly ($P<0.05$) different.
[x]Carbohydrate content was calculated by difference.
[y]S.E.M, Standard error of the mean.

Table 2.4
Effects of muscle type on yield, shear force and expressible moisture of bison top round

Interaction	Cooking yield (%)	Shear force values (N)[x]	Expressible moisture (%)
adductor (ADD)	69.4ab	74.1b	16.3a
gracilis (GRA)	68.3ab	77.0a	12.2b
pectineus (PEC)	70.1a	73.6b	15.2a
semimembranosus (SM)	66.8b	77.2a	10.0b
S.E.M.[y]	1.28	1.02	0.50

Data are pooled across cooking methods.
a-b, Means with different letters in the same column are significantly ($P<0.05$) different.
[x]SFV, shear force value (N = Newton, SI unit of force), a Newton can be converted into kg force by dividing the N value by 9.80665.
[y]S.E.M, Standard error of the mean.

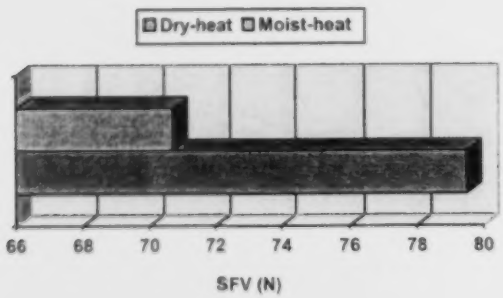
Table 2.5
Effects of muscle type and cooking method interaction on yield, shear force and expressible moisture of bison top round

Interaction		Cooking yield (%)	Shear force values (N)[x]	Expressible moisture (%)
Muscle*cooking method				
adductor (ADD)	Dry-heat	65.8b	79.4a	14.3b
	Moist-heat	73.0a	70.7b	18.4a
gracilis (GRA)	Dry-heat	64.8b	82.4a	8.4b
	Moist-heat	74.8a	71.6b	16.0a
pectineus (PEC)	Dry-heat	64.6b	79.3a	14.3a
	Moist-heat	74.2a	67.9b	16.1a
semimembranosus (SM)	Dry-heat	64.6b	85.3a	6.4b
	Moist-heat	75.3a	69.0b	13.4a
S.E.M.[y]		0.78	1.45	0.71

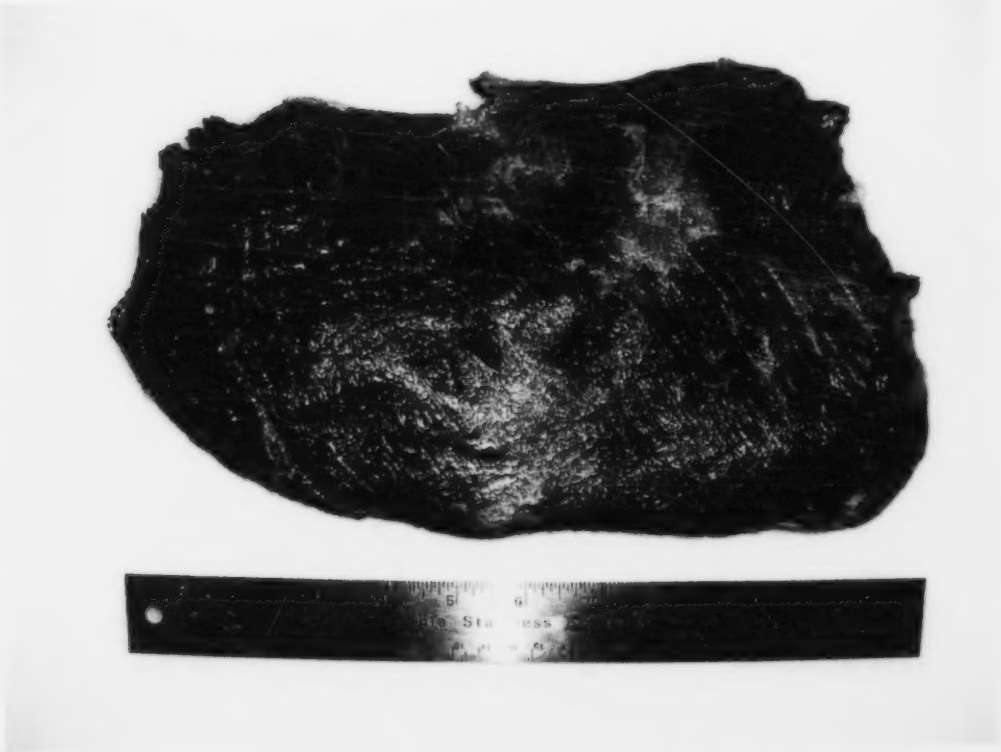
a-b, Means with different letters in the same column (within each muscle*cooking group) are significantly ($P<0.05$) different.
[x]SFV, shear force value (N = Newton, SI unit of force), a Newton can be converted into kg force by dividing the N value by 9.80665.
[y]S.E.M, Standard error of the mean.

ADDUCTOR

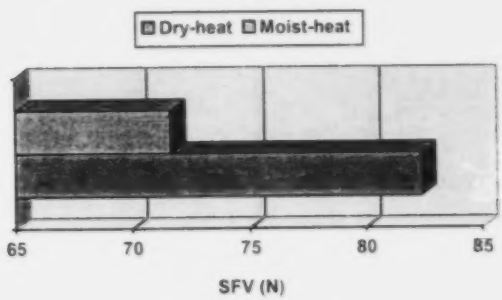
This is a thick triangular muscle that lies between the femur and the ***semimembranosus*** with the ***pectineus*** muscle lying anterior to it.



GRACILIS

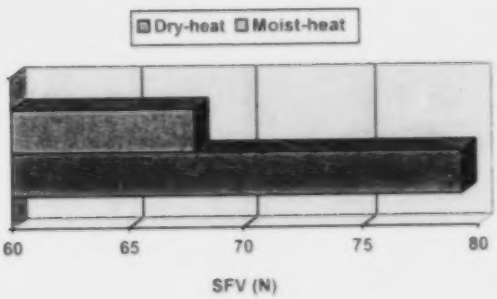


It is a flat muscle that lies directly over the *semimembranosus* and *adductor*.



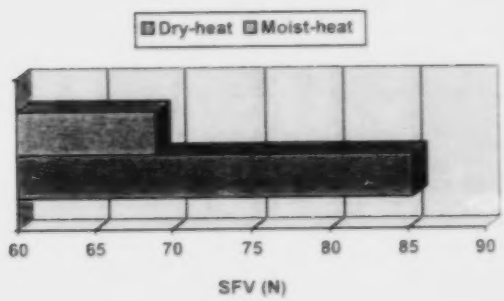
PECTINEUS

It is a small cone-shaped muscle that lies adjacent to the *adductor* muscle.



SEMIMEMBRANOSUS

It is largest of all top round muscles, and lies beneath the *gracilis* muscle.



Activity 3. Influence of level of moisture-enhancement and marinade composition on the texture of bison meat

1. Introduction and objectives

Due to a growing interest in marinated meat products, supermarket shelves now offer a wide range of cooked, chilled marinated products to satisfy consumer demand. These marinated meats are also known as "moisture-enhanced meats" or "enhanced meats." Enhanced meats are becoming more and more popular in North America. This trend is well established with pork and poultry processing and is spreading to beef products. Enhanced meat can be defined as fresh, whole muscle meat that has been injected with an aqueous solution containing ingredients such as salt, phosphates, antioxidants and flavourings.

Below are the most common reasons for enhancing meats:

- **Appearance, tenderness, juiciness and flavour**: Injecting meat with a solution containing phosphates results in better meat colour. Due to food safety concerns, consumers tend to overcook pork and poultry products. Enhanced meats, if properly processed, can retain more moisture than non-enhanced counterparts, even when overcooked, resulting in a more tender mouthfeel. To cater to the demands and needs of health-conscious consumers internationally, there has been a push to breed leaner domesticated animals, which consequently has led to a reduced flavour in cooked meat products, especially those of pork. Various herbs, spices and flavourings in marinade solutions can help address this issue.

- **Consumer convenience**: Consumers are spending much less time preparing meals than they did 10-20 years ago. Also, many people lack confidence in how to select and prepare meat. Enhanced meats are practically ready to cook, requiring very little preparative time, and offer great taste to the average consumer.

- **Reduced "purge"**: Purge is the liquid that accumulates in the bottom of a meat package during display in the retail case. Purge is not attractive to consumers and causes some retailers to remove and discard these products well before their shelf-life expiration date. This leads to lost revenues for retailers and higher prices for consumers. Purge also occurs when frozen meats are thawed. Injecting a solution containing salt and phosphate into fresh meat can help "tie up" water and thereby minimize purge. Depending upon the desired texture for the meat product, too much extension or pump can lead to visible purge in the package; therefore, moisture enhancement has a limit and must be optimized for meat from each species. For example, pork and poultry products can be enhanced to nearly 30%, whereas, extension levels of only *ca.* 10% are used by the industry for beef products.

- **New product development**: Enhanced meat allows for the development of new processed fresh meat products that were previously not possible, like pre-marinated ready-to-cook meats. Such products simplify the meal plans of busy consumers.

- **Increased profitability**: Through "adding value" to meat by enhancing it, meat producers can charge more for their products and achieve higher profits. Also, by solving the problems of colour retention and purge, enhanced meat facilitates the trend toward case-ready meat; *i.e.*, meat that is processed and packaged at the meat packing plant so it is immediately ready for display and sale in retail stores.

When meat is injected with a solution to enhance its moisture and flavour, there is a possibility that spoilage or pathogenic microorganisms present on the surface can be introduced into the interior of the meat product. This can lead to food safety concerns, especially when the interior of products do not reach temperatures sufficient to destroy all bacteria. Therefore to help ensure food safety for consumers, the marinade solutions are kept at refrigeration temperatures and the processing of these products is carried in temperature-controlled plants. Also, food-grade additives like sodium L-lactate (*NB*, which is now approved in Canada) can be added to the marinade solution, which delays

or inhibits the growth of spoilage microorganisms, thus extending the shelf life of the meat product. Good manufacturing and processing practices are always important in any food product including marinated meat products.

Dilute salt and phosphate marinades are routinely employed by the meat industry to enhance the quality of meat and meat products. Although dilute salt or phosphate solutions may be used alone, they are often added in combination to fresh meat to exploit their synergistic action (Dhanda *et al.*, 2002, 2003; Sheard and Ali, 2004). Their utilization not only improves the juiciness and tenderness of resultant products when cooked, but they also increase the weight of the saleable product, due to the retention of added water. The mechanism responsible for the increased tenderness and juiciness is connected with higher water holding and swelling of myofibrils (Offer and Knight, 1988). In a study on bison meat (Dhanda *et al.*, 2002), brine solutions for moisture-enhancement to achieve a 10% extension by weight with 0.5% sodium chloride and 0.3% sodium tripolyphosphate in the finished marinated product were employed. The present study was designed to assess the effects of different levels of extension and the various concentrations of sodium tripolyphosphate, which can be used in the marinade formulation, on the yield and tenderness of moisture-enhanced bison bottom round steaks.

2. Materials and methods

2.1. Sampling and processing procedures

Bison bottom rounds (15) were acquired from a federally-inspected slaughter facility and trimmed of any visible fat. *Biceps femoris* muscles were separated from the bottom rounds and used in this study. Each of these muscles was divided into almost 5 equal portions and randomly subjected to various treatments as described below.

Injection levels and brine solutions were formulated to achieve the desired concentrations of sodium chloride (NaCl) and sodium tripolyphosphate ($Na_5P_3O_{10}$, STPP) in the finished marinated product and these treatments were named as under:

- **CON**, control;
- **10P2**, 10% extension with marinade containing 0.2% STPP and 0.5% NaCl;
- **10P4**, 10% extension with marinade containing 0.4% STPP and 0.5% NaCl;
- **20P2**, 20% extension with marinade containing 0.2% STPP and 0.5% NaCl; &
- **20P4**, 20% extension with marinade containing 0.4% STPP and 0.5% NaCl.

The brine solution used for injection was kept at –1°C overnight and a temperature of 2±1°C was achieved just before injection. The sections designated for marination were injected using a Fomaco Reiser multi-needle injector (Picture 3.1, Model FGM20/40, Fomaco Reiser, Burlington, ON, Canada) to the desired target weight gain (*i.e.*, either 110 or 120%) over the raw meat or "green" weight. Re-injection with a hand held injector compensated for any difference in the target weight. Sections were allowed to equilibrate for 5 min following injection to permit draining. The actual injection level attained = (injected weight / raw weight) x 100, was calculated for all marinated muscle sections (15 x 4 = 60). During the experiment, all processing was carried out in a refrigerated (8±2°C) pilot plant.

After moisture-enhancement, muscle samples were sliced, starting from the centre and then moving proximally and distally along the longitudinal plane, so as to obtain 3 one and a half inch (3.81 cm) thick steaks. These steaks were used for evaluation of tenderness after grilling to an internal temperature of 72°C.

2.2. *Cooking of steaks and evaluation of tenderness*

Steaks were cooked using an electric grill (Garland ED-30B electric grill; Condon Barr Food Equipment Ltd, Edmonton, AB). Steaks were placed on the grill, preheated to 210°C, cooked until an internal temperature of 40°C was reached and then turned and cooked to 72°C. The temperature of the steak was monitored using copper-constantan OMEGA Type-T thermocouples (OMEGA Engineering Canada, Inc., Laval, QC, Canada) attached to a scanner (Model 692-8000, Barnant Co., Barrington, IL, USA) and a computer, which recorded the change in temperature at 30-s intervals. Cooking yield = (cooked weight /raw weight at cooking) x 100, was recorded for each steak.

After cooling to an internal temperature of 50°C, cooked steaks were over-wrapped with Saran® wrap to prevent evaporative loss and held overnight in a 4°C cooler. Then, 6-8 cores (1.27 x 1.27 x 3.81 cm) were removed at random from each steak parallel to the direction of the muscle fibres. Cores were allowed to equilibrate to room temperature for an hour before tenderness measurements (*i.e.*, shear force values) were carried out using a Food Technology Corporation, TMS-TP Texture Press (Rockville, MD, USA), TMS-90 Computer, and a Warner-Bratzler Shear Test Cell with a FTA 3000 Transducer (Picture 3.2).

2.3 Statistical Analysis

The effects of level of moisture-enhancement and marinade composition (5 treatments, CON, 10P2, 10P4, 20P2 and 20P4) on cooking yield and shear force values of bison meat were analyzed using the General Linear Model (GLM) procedures of the SPSS statistical package (SPSS, 1999). Least-squares means (LSM) and standard errors of the mean (SEM) for all parameters used in the study were computed and tested for differences between treatments. Significance levels between the treatments for a particular parameter were assessed at $P<0.05$ as stated in the results.

3. Results and discussion

The average yields achieved for injected sections (15 each) were as follows: 110.2% for 10P2, 111.1% for 10P4, 119.6% for 20P2 and 120.6% for 20P4.

Recommended addition levels of STPP to fresh meat are less than 0.5%, because higher concentrations have been reported to impart a soapy/metallic flavour to products (Claus *et al.*, 1994). In a previous study we employed STPP levels of 0.3% in the marinade for bison meat (Dhanda *et al.*, 2002); according to a consumer panel, addition of STPP improved the texture and acceptability of the enhanced meat, and imparted no adverse flavour to the cooked product. With this in mind, different levels of STPP (0.2 and 0.4%) were tested in the present study to find a balance between the optimum level

and positive effects of STPP on meat quality. The sodium chloride concentration remained constant at 0.5% in all marination treatments so that the effect of STPP level could be investigated; greater than 0.5% salt has been reported to produce products that are too salty after cooking as well as adversely affecting the flavour (Claus *et al.*, 1994).

All marinated steaks from the bottom rounds had significantly ($P<0.05$) greater cooking yield compared to control ones (76-81 *vs* 68%). Level of injection also influenced the cooking yield: steaks with 20% extension (20P2 and 20P4) had higher cooking yields (~ 5%) compared to those from 10% extension (10P2 and 10P4); however, within injection treatments, the level of STPP did not have any effect on the yield. A similar trend was observed for tenderness (*i.e.*, shear force values): steaks from 20P2 and 20P4 treatments exhibited significantly ($P<0.05$) lower (~ 10%) shear force values compared to those from 10P2 and 10P4. All enhanced steaks were significantly ($P<0.05$) more tender than control steaks: steaks with 10% enhancement had 21% and those with 20% extension had 30% lower shear force values than control counterparts. Similar findings have been reported by Dhanda *et al.* (2002) for bison *semimembranosus* steaks and roasts with shear values of 102 and 64 N for non-injected and injected samples, respectively.

In the present study, the recorded mean shear force values for control samples were 95 N, which fall under the "tough" category, while shear values for marinated samples were in the range of 65-75N, which are considered under the "probably tender" category (Aalhus *et al.*, 2000). Kolle *et al.* (2004) reported an average shear force values of 37 N for beef *biceps femoris* muscle. It is difficult to compare absolute shear force values amongst published studies because of variations between animals (*i.e.*, different genotype, feeding regimes, age and gender) as well as different sampling, cooking and measurement techniques.

Level of enhancement (*i.e.*, percent extension) influenced the tenderness of steaks; however, shear force values did not differ ($P>0.05$) for the level of STPP (0.2 *vs* 0.4%) within each injection level. These findings suggest that a STPP level as low as 0.2% in

the finished marinated product is sufficient to achieve positive effects of moisture enhancement with polyphosphates.

4. Conclusions and recommendations

Marination or moisture-enhancement has a great deal of potential in improving the texture of bison meat. A level of 0.5% NaCl combined with 0.2% STPP in the finished marinated *biceps femoris* steaks was sufficient to improve the cooking yield, while both marination levels (10 and 20%) improved shear values of bison meat steaks. Processors could successfully employ enhancement to produce value-added meat products from lesser-values cuts of bison. Opportunities can further be widened by using combinations of different herbs, spices and flavours in the marinade solutions. To increase the acceptance of these enhanced lesser-utilized cuts by the consumers, it is recommended that recipes for new products be developed in association with a culinary chef. Collaboration opportunities with the Saskatchewan Food Industry Development Centre aught to be explored for developing and marketing of these value-added products.

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Table 3.1
Effects of moisture enhancements and marinade composition on cooking yield and shear force of bison *biceps femoris* steaks

Treatment	Cooking yield (%)	Shear force values (N)[x]
CON	68.1c	95.3a
10P2	77.0b	75.6b
10P4	76.0b	73.9b
20P2	80.9a	64.2c
20P4	80.1a	64.9c
S.E.M.[y]	1.10	1.49

Treatments: CON, control; 10P2, 10% extension with marinade containing 0.2% STPP and 0.5% NaCl; 10P4, 10% extension with marinade containing 0.4% STPP and 0.5% NaCl; 20P2, 20% extension with marinade containing 0.2% STPP and 0.5% NaCl; 20P4, 20% extension with marinade containing 0.4% STPP and 0.5% NaCl.
a-b, Means with different letters in the same column are significantly (P<0.05) different.
[x]SFV, shear force value (N = Newton, SI unit of force), a Newton can be converted into kg force by dividing the N value by 9.80665.
[y]S.E.M, Standard error of the mean.

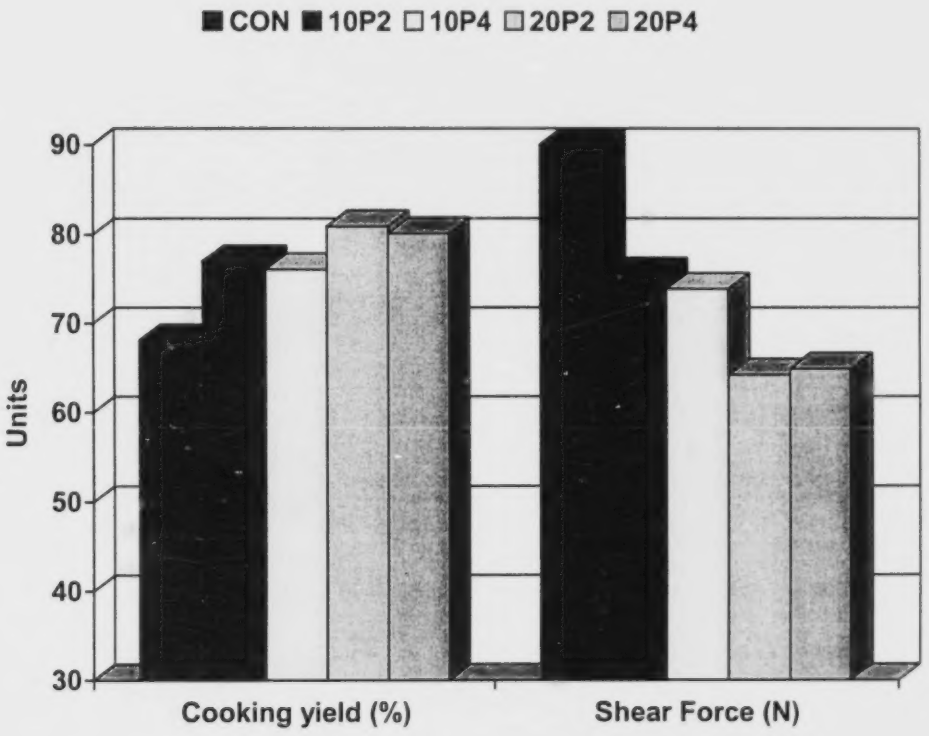
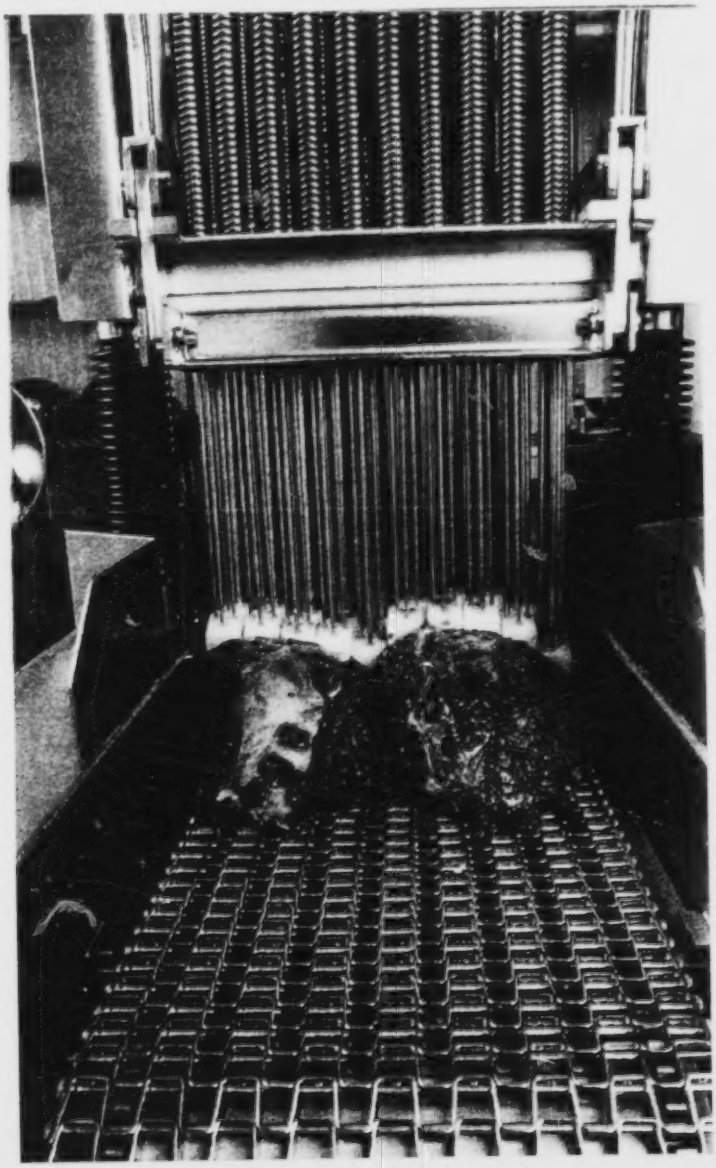
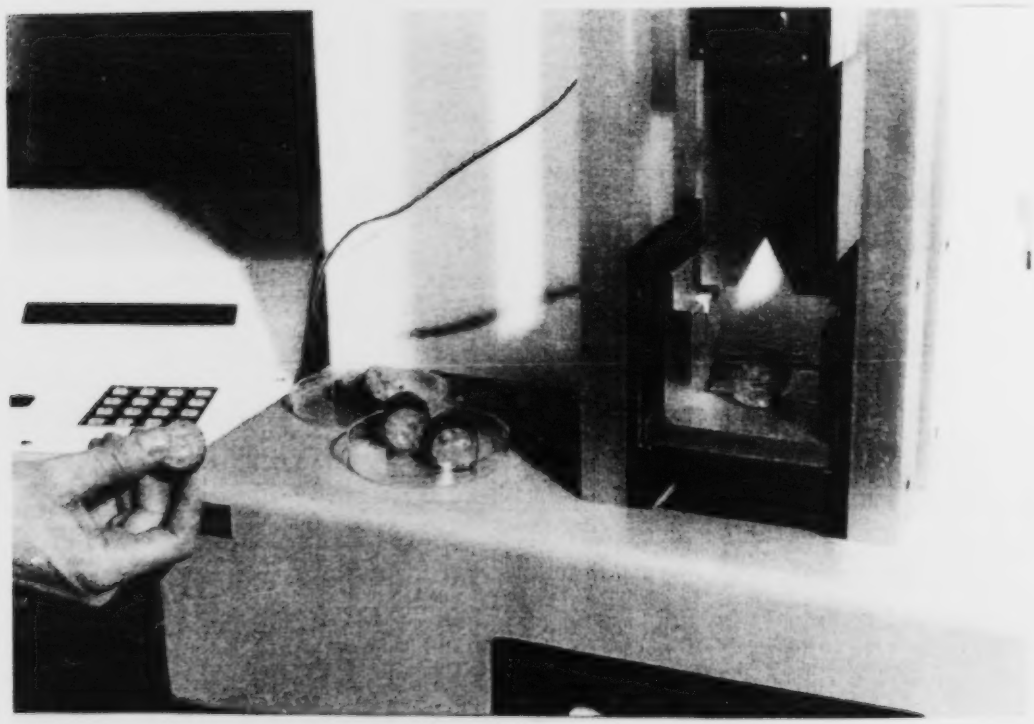


Figure 3.1. **Effects of moisture-enhancements and marinade composition on cooking yield (%) and shear force values (N) of bison *biceps femoris* steaks. Treatments: CON, control; 10P2, 10% extension with marinade containing 0.2% STPP and 0.5% NaCl; 10P4, 10% extension with marinade containing 0.4% STPP and 0.5% NaCl; 20P2, 20% extension with marinade containing 0.2% STPP and 0.5% NaCl; 20P4, 20% extension with marinade containing 0.4% STPP and 0.5% NaCl.**



Picture 3.1. Mechanical injection of brine into meat pieces.



Picture 3.2. Texture press machine depicting a Warner-Bratzler shear cell.

Activity 4. Optimization of still marination: Effects of still marination and mechanical tenderization on the tenderness and consumer acceptability of bison meat

1. Introduction and objectives

As has been noted, there has been a growing interest in the marination or "enhancement" of meat products among consumers. Marination is a traditional culinary technique used to tenderize and improve the flavour of fresh meat. Originally, organic acids were the main ingredients in a marinade, because improvement in meat tenderness was achieved when the pH of the meat was sufficiently lowered to create a more acidic environment: under these conditions, collagen is more susceptible to degradation during cooking (Gault, 1991). In recent times, however, salt and poly-phosphates have been routinely incorporated into marinades to enhance the quality of meat and meat products. At the industrial scale, mechanical injectors are employed to produce moisture-enhanced meat products. Though these injectors do a wonderful job in terms of uniformly distributing the enhancement solutions throughout the meat pieces, cost is always a factor, especially for the small meat processor. To address this issue, a still-marinating process was examined to assess the suitability and benefits attributed to marination.

Tumbling or massaging of pickle-injected meat cuts is employed to speed up the curing process, to facilitate extraction of salt-soluble proteins, and to improve the texture, bind, water-holding capacity and the yield of finished products. Tumblers are large stainless steel units that rotate in a circular fashion for a period of time. Nowadays practically all units have vacuum capabilities. Inside, pieces of meat are continuously lifted up by baffles to the upper part of the machine. Form here they fall, striking the meat mass below, and produce an intense mechanical action suitable for high yield products. Muscle fibres are disrupted by this mechanical action, which makes cellular membranes more permeable and facilitates the distribution and absorption of brine. Some degree of massaging also occurs as the chunks slide over each other as the tumbler turns.

Tumblers typically provide somewhat more of a destructive effect than massagers on account of the impact force generated from the mechanical action. Thus, not all processed meat products can be tumbled. A fitting example for the benefits comes from ham production: hams processed in this fashion are more uniform, as brine uptake is more tightly controlled and pickle pockets are reduced. The tighter control of pickle uptake results from the ability to pump hams at, or somewhat below, the target pump and then adjusting the product's uptake to the exact percent pump by adding pickle directly to the tumbler. Without the presence of tumblers and massagers in meat processing operations, the higher processing yields and lower production costs associated with a number of value-added meat products could not be achieved. Tumbling can be used alone or in combination with marination to enhance uptake of marinade (Claus *et al.*, 1994).

Blade tenderization is another technique, which has been used by the industry to tenderize meat, especially that from older animals. During blade tenderization, thin needle type blades penetrate meat chunks and disrupt both connective tissue and the myofibrillar contractile system, thereby reducing the shear force values and the amount of organoleptically detectable connective tissue (Bidner *et al.*, 1985; Jeremiah *et al.*, 1999; Seideman *et al.*, 1977; Tyszkiewiecz and Jakubiec-Puka, 1995). Commercial blade tenderization devices are often used for infusing solutions into meat, and these solutions may contribute to tenderization. Histological examination of treated meat samples shows that the muscle fibres are torn and fragmented by the blade, as is connective tissue, but areas between points of blade penetration will be unaffected. Despite this localized effect, the density of blades compensates and this technique confers significant improvement to a range of cuts; this is particularly so for some of the toughest cuts of the hind leg, such as the top round. In contrast, there is much less benefit from blade tenderization for inherently tender cuts, such as the loin.

The still-marinating process requires more space and time than traditional processes for marination. Nevertheless, the investment cost is much lower compared to mechanical injection, tenderizing, and tumbling, as these techniques require more sophisticated equipment. The objectives of the present research were to optimize the marinating time

for still marination of bison bottom round steaks and to compare different combinations of still marination, blade tenderization and tumbling for their influence on the texture of bison meat.

2. Materials and methods

2.1 Sampling and processing procedures

Bison bottom rounds (10) were acquired from a federally-inspected slaughter facility and trimmed of any visible fat. *Biceps femoris* muscles were separated from the bottom rounds and were used in this study. Each of these muscles was divided into 10 one and a half-inch thick steaks and randomly subjected to the following treatments:

- CON – Control;
- SM – Still Marination;
- BT – Blade Tenderization;
- SMT – Still Marination followed by Tumbling; &
- BTSM – Blade Tenderization followed by Still Marination.

For SM, steaks were immersed in a bag for 72 h in a brine solution containing sodium chloride and sodium tripolyphosphate to achieve a ~ 10% extension by weight. The brine (2±1°C) prepared for injection into steaks was formulated to achieve 0.5% sodium chloride and 0.3% sodium tripolyphosphate in the finished marinated product. For SMT treatment, steaks, after being immersed in brine in sealed polythene bags, were tumbled without vacuum for 15 min in Vario-Vac tumbler (Model VV1-150, Killvoangen, Germany). The steaks designated for BT were passed once through a Jaccard® meat tenderizer (Jaccard® Model H No. B4590, Orchard Park, NY, USA, Picture 4.1). The tenderizer's blades were aligned perpendicular to the direction of the muscle fibres. BTSM steaks were still marinated after BT treatment, while steaks without any treatment were kept as a control for comparison. For the experiment all processing was carried out in a refrigerated (8±2°C) pilot plant.

2.2. *Standardization of still marination*

To monitor salt and polyphosphate diffusion during the still-marination process, a preliminary trial was conducted, where 20 one and a half-inch thick steaks from *biceps femoris* muscle were weighed and still marinated at –1°C in individual bags containing the prepared brine, to which 200-ppm sodium nitrite had been added. After every 24 h, a batch of 3 steaks was removed from the cooler and reweighed to determine the brine uptake. Then, these steaks were cooked to an internal temperature of 72°C. After thermal processing, the steaks were sliced longitudinally and the extent of sodium nitrite penetration was assessed visually. In regions where nitrite had penetrated, the muscle tissue was red/pink in appearance due to the formation of the cooked cured-meat pigment, mononitrosyl haemochromogen. Those areas in which nitrite had not diffused into appeared brown, which is characteristic colour of denatured metmyglobin. In essence this simple technique developed from Dr. RB Pegg's Ph.D. research helped to indicate how long samples needed to marinate to ensure complete penetration of sodium chloride and tripolyphosphate throughout the muscle tissue. After the experiment, it was concluded that 72 h were needed for complete penetration and almost 10% extension in the weight of the steaks.

2.3. *Cooking of steaks and evaluation of tenderness*

After treatments, steaks were cooked using an electric grill (Garland ED-30B electric grill; Condon Barr Food Equipment Ltd, Edmonton, AB) as described in the Activity 3.

2.4. *Consumer evaluation of bison steaks*

Consumer panellists between the ages of 18 and 65 were selected for participation in the panel. Panellists were screened to ensure the following:

- They are regular beef eaters;
- They eat steak at least once per month;
- They generally eat their steak, which are prepared medium rare, medium or medium well; &

- They have no prejudice for consuming game meat.

Testing was conducted at the Consumer Product Testing Centre in Edmonton, AB, by the Sensory Program of the Food Processing Development Centre (AAFRD), over 2 days, with 33 panellists participating on the first day, and 38 on the second day, for a total of 71 consumers.

Steaks were stored frozen until the day before the evaluation, at which time they were thawed for 24 h at 4°C. Fifteen-cm stainless steel probes attached to a thermocouple wire (Type J) were inserted into the geometric centre of each steak. Thermocouples were attached to a data logger (Campbell Scientific CR5000) interfaced with computer software to display the temperatures of each steak at 5-s intervals. Steaks were grilled on a Garland (Model ED-30B, Garland Commercial Ranges Ltd., Mississauga, ON) electric open-hearth broiler to an internal temperature of 72°C. The grill was set to the 5.0 setting, and steaks were turned over when they reached a temperature of 40°C to reduce the incidence of charring. Placement on the grill of the treatments and order of service to panellists were determined following a Williams Square design. Start times for cooking of the steaks were staggered, according to the design, but due to extreme variations in cooking times, steaks were stored in a food warmer, set to 60°C, before being served to panellists.

Steaks were trimmed on the ends after cooking and cut into quarters around the centre point for service to panellists. The samples were served on coded 15-cm foam plates with metal forks and steak knives. Panellists evaluated the samples in individual booths. They were instructed to cleanse their palate with unsalted crackers and water before tasting each sample. Each panellist received his or her 5 samples of steak (one per treatment) from a single animal. Treatments (Control, CON; Still Marination, SM; Blade Tenderization, BT; Still Marination followed by Tumbling, SMT; and Blade Tenderization followed by Still Marination, BTSM) were assigned different codes each day.

Steak samples were evaluated using a computerized version of the ballot for sensory attributes (*i.e.*, appearance, tenderness, flavour, juiciness and overall acceptability)

based on a 6-point scale, where 1 = dislike very much and 6 = like very much. The intensity of tenderness, flavour and juiciness was also evaluated based on a 6-point descriptive scale (*i.e.*, for tenderness, 1 = very tough and 6 = very tender; for flavour, 1 = very bland and 6 = very intense; and for juiciness, 1 = very dry and 6 = very juicy). Buying decision for the steaks was evaluated based on a 4-point scale, where 1 = definitely not and 4 = definitely yes (see Appendix 2 for further details).

2.5. Statistical Analysis

The effects of type of treatment (5; CON, SM, SMT, BT and BTSM) on cooking yield, shear force values and consumer acceptability of bison meat were analyzed using the General Linear Model (GLM) procedures of the SPSS statistical package (SPSS, 1999). Least-squares means (LSM) and standard errors of the mean (SEM) for all parameters used in the study were computed and tested for differences between treatments. Significance levels between the treatments for a particular parameter were assessed at $P<0.05$, as stated in the results.

3. Results and discussion

After 72 h of still marination, average yields achieved for steaks from marinated treatments were as follows: 109.5% for SM, 109.9% for SMT and 110.6% for BTSM.

3.1. Relationship between cooking yield and tenderness

The cooking yield does influence tenderness of meat! A higher cooking yield means more moisture retention; resultant products are more tender than products with lower yields on cooking. Textural changes in myofibrillar and connective tissue proteins predominantly influence the tenderness of meat after cooking. Depending on the method of thermal processing and degree of doneness, there also occurs a loss in moisture during cooking. Cooking losses are increased as the cooking temperature and end-point temperature increase. Consequently, this leads to a decrease in juiciness, high cooking losses along with protein hardening and toughening induced by high

cooking temperatures, which markedly reduce tenderness. As mentioned earlier, marination or moisture enhancement can compensate for some of the normal/expected cooking losses, thereby keeping the meats juicier than non-marinated products. With marinated products, the overall palatability of meat is not compromised irrespective of the degree of doneness.

The tenderness of meat is one of the most important factors influencing palatability. Considerable research over the past century has focused on understanding all aspects of meat tenderness. To do this quantitatively, a number of mechanical devices were developed to accurately discriminate between different extents of tenderness. The Warner-Bratzler shear measurement device is easily the most widely used and accepted method to determine the tenderness of meat. The original device, developed in the 1930s, was comprised of a thin steel blade with a circular hole in the middle, that would hold a meat sample, and a wooden mitre box, which the steel blade would slide through. Since then, modifications to the device have been made. For example, the shape of the steel blade and the hole in the centre were both changed to be triangular, and the points of the triangular hole were rounded. The sample size of the meat product being sheared was standardized to be a cylindrical core with a one-half inch diameter, and a parallel fibre orientation. Advances in engineering and electronics have allowed the Warner-Braztler shear device to be adapted to computerized devices such as the texture press machine (see Picture 3.2 in Activity 3).

Warner-Bratzler shear force values are the amount of force required to shear a core of a meat sample; they are commonly reported in pounds, kilograms or Newtons. What do these values actually mean? Higher shear force values denote a lower degree of tenderness. As a starting point, Warner-Bratzler shear forces values can be used to establish differences in tenderness between two different muscle samples or they can be correlated to consumer tenderness perceptions.

3.2. *Effects of various treatments on cooking yield and tenderness*

The effects of various treatments on the cooking yield and tenderness are presented in Table 4.1 and Figure 4.1. Marinated steaks had significantly ($P<0.05$) better cooking yields than non-marinated analogues. SM, SMT and BTSM steaks had cooking yield of ~ 80% compared to 69% for BT and CON steaks. There was no significant ($P>0.05$) difference, however, in cooking yield between CON and BT steaks or among steaks subjected to SM, SMT and BTSM. As noted previously, cooking yield can be increased by marinating meat and meat products with salt and phosphates. Alkaline phosphates such as STPP increase pH, thereby improving the water-holding capacity and cooking yield. Similar findings have been observed by our group in previous studies (Dhanda *et al.*, 2002, 2003 and Pietrasik *et al.*, 2005).

Blade tenderization significantly ($P<0.05$) decreased the shear values of steaks compared to control steaks; however, a maximum positive effect on tenderization was observed when still marination was combined with either tumbling or blade tenderization. Shear force values decreased by 9% for BT steaks, where as the decrease in shear values was close to 30% for SMT and BTSM steaks when these compared to control ones. Davis *et al.* (1977) and Glover *et al.* (1977) reported that mechanical tenderization techniques such as blade tenderization markedly reduced shear values but could increase cooking losses, which might offset the tenderness advantage. This was evident in the present study from higher cooking losses for BT steaks. SMT and BTSM steaks were most tender, followed by SM and BT steaks, whereas CON steaks were least tender (*i.e.*, they had the highest shear force values). These findings have reiterated the importance of marinating meat from specialty species like bison on account of their leanness. Higher shear force values of such meats can be attributed to lower fat cover and/or juiciness and hardening of myofibrillar proteins, when these meats are subjected to thermal processing, especially dry-heat cooking like baking or grilling. Marination or moisture enhancement can easily compensate for most of the cooking losses for lean meats like that from bison.

3.3. Consumer evaluation

Demographic distribution of the consumer panel is presented in Table 4.2, Figure 4.2 and Figure 4.3. The panel was selected to have a good representation of the consumers across gender and various age groups. Out of a total of 71 consumers, male (48%) and female (52%) had an almost equal representation. From the 5 age groups selected, 33% represented "55-65 years", 9% were from "18-24 years", 24% were from "25-34 years" and 18% each belonged to "35-44 years" and "45-54 years" age groups.

The consumer response for the effects of still marination and other treatments on sensory attributes (*i.e.*, appearance, tenderness, juiciness, flavour and overall acceptability) is reported in Table 4.3 and illustrated in Figure 4.4. Still marination and its combination treated steaks (*i.e.*, SM, SMT and BTSM) were perceived to be significantly ($P<0.05$) juicier, more tender and had better flavour compared to non-marinated steaks (*i.e.*, CON and BT). The results obtained from the consumer panel support the findings of mechanical evaluation of tenderness of bison *biceps femoris* steaks; however, results did not fully correspond to shear values (Table 4.1). Consumers were unable to significantly ($P>0.05$) differentiate samples within marinated (*i.e.*, SM, SMT and BTSM) and non-marinated (*i.e.*, CON and BT) groups, respectively. As already mentioned, higher cooking losses of blade tenderized might be responsible for significantly ($P<0.05$) lower acceptance of BT steaks compared to SM, SMT and BTSM steaks. Overall consumers preferred marinated steaks to non-marinated ones; tenderness, flavour and juiciness, significantly ($P<0.05$) increased as a result of marination and were found to be the most important factors with respect to consumer eating satisfaction. Hence, marination seems to be protecting against moisture loss during grilling of these steaks. Vote *et al.* (2000) and Robbins *et al.*, (2003) reported similar findings: moisture enhancement significantly increased the consumer acceptability of beef steaks and roasts. One of the limiting factors in the acceptance of meat products from specialty livestock such as bison is the fact that they tend to be very lean and are often overcooked. Resultant products are very dry and give the consumer an unpleasant eating experience. As already mentioned, this can be overcome easily by inclusion of marinades at levels sufficient to compensate for most for the cooking losses, as was done in the present study. Marinated meat products are more succulent and

offer consumers a satisfying eating experience without losing the characteristic flavour of the meat.

4. Conclusions and recommendations

Small processors who cannot afford mechanical injectors and have small volume of meat to process can use still marination successfully. Advantages of still marination can further be enhanced if it is combined with tumbling or blade tenderization. Consumer acceptance of lesser-value meat cuts from bison can be improved through marination of such meats and by educating the consumer on cooking techniques for lean meats.

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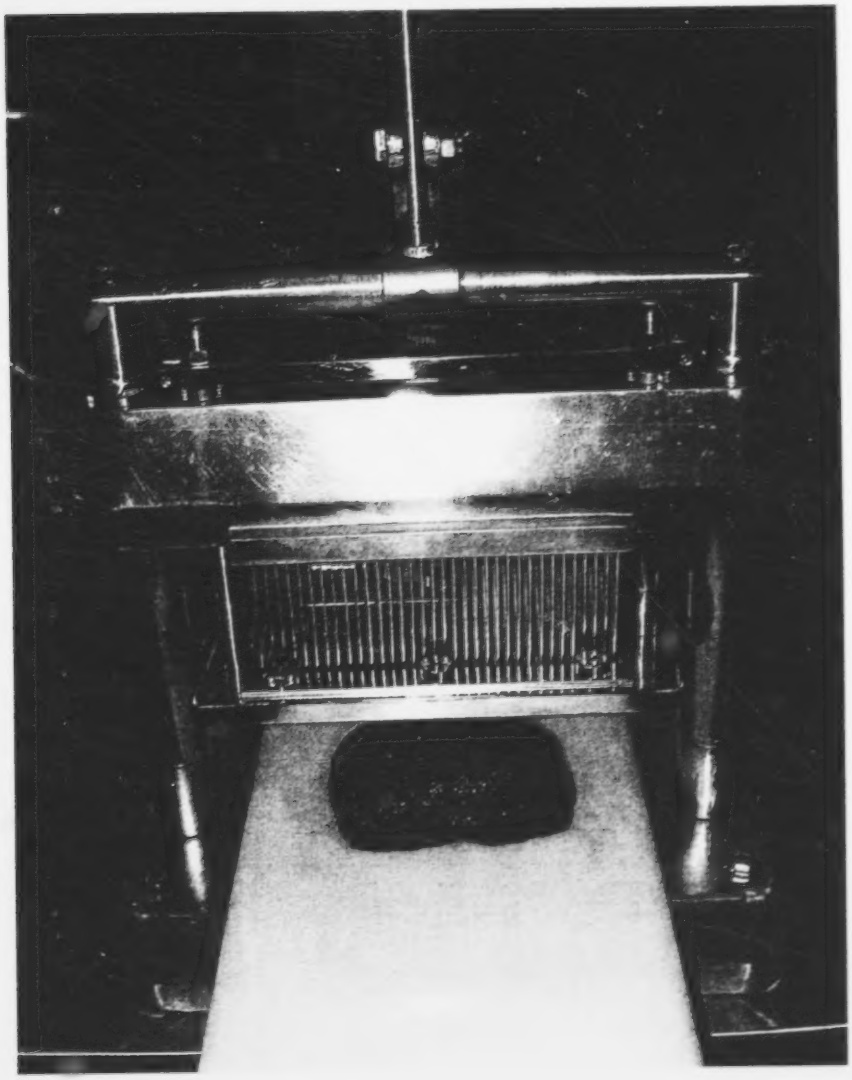
Table 4.1
Effects of treatment type on cooking yield and shear force of bison *biceps femoris* steaks

Treatment[x]	Cooking yield (%)	Shear force values (N)[y]
Control (CON)	69.5b	76.3a
Still Marination (SM)	81.2a	63.0c
SM followed by Tumbling (SMT)	79.7a	52.1d
Blade Tenderization (BT)	69.1b	69.4b
BT followed by Still Marination (BTSM)	79.8a	53.0d
S.E.M.[z]	0.79	2.85

a-b, Means with different letters in the same column are significantly ($P<0.05$) different.
[x]Treatments: CON, control; SM, still marination; SMT, SM followed by tumbling; BT, blade tenderization; BTSM, BT followed by SM.
[y]SFV, shear force value (N = Newton, SI unit of force), a Newton can be converted into kg force by dividing the N value by 9.80665.
[z]S.E.M, Standard error of the mean.



Picture 4.1. Jaccard® meat tenderizer.

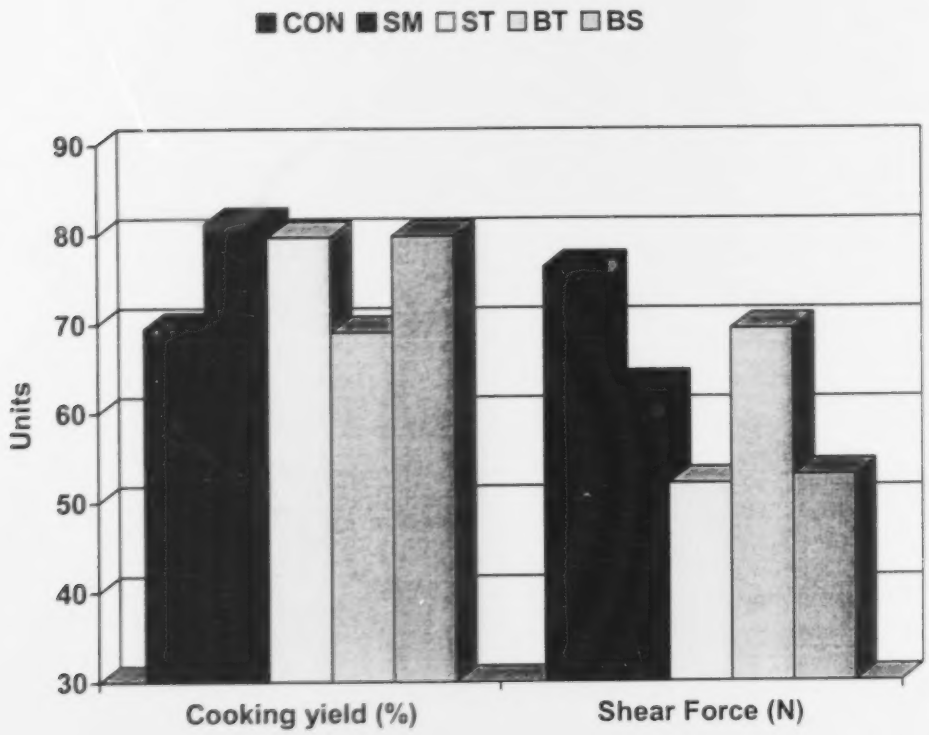


Figure 4.1. **Effect of treatment type on cooking yield (%) and shear force values (N) of bison *biceps femoris* steaks. Treatments: CON, control; SM, still marination; SMT, SM followed by tumbling; BT, blade tenderization; and BTSM, BT followed by SM.**

Table 4.3
Demographic distribution of the consumer panel

Age group (Age in years)	Sex		Total
	Male	Female	
18-24	5	1	**6**
25-34	10	7	**17**
35-44	3	10	**13**
45-54	6	7	**13**
55-65	10	12	**22**
Total	**34**	**37**	**71**

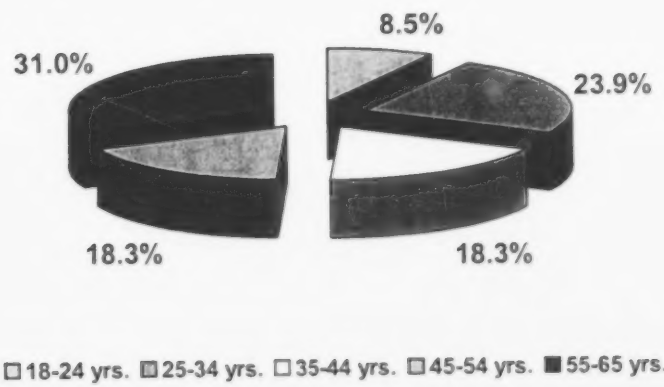


Figure 4.2. Proportion of various age groups in the selected consumer panel.

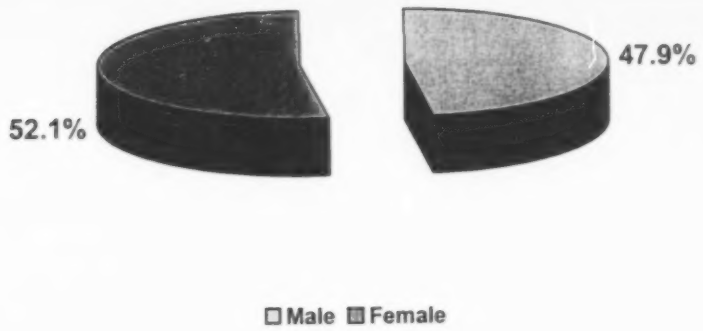


Figure 4.3. Gender distribution in the selected consumer panel.

Table 4.2
Effects of treatment type on sensory attributes of bison *biceps femoris* steaks

	Treatments[x]					
Attributes[y]	**CON**	**SM**	**SMT**	**BT**	**BTSM**	**S.E.M.[z]**
Appearance	4.40ab	4.70a	4.61ab	4.24b	4.48ab	0.16
Tenderness Accept.	3.15b	4.59a	4.61a	3.46b	4.76a	0.15
Intensity	2.85b	4.58a	4.65a	3.24b	4.87a	0.14
Juiciness Accept.	3.18b	4.86a	4.65a	3.27b	4.68a	0.14
Intensity	3.03b	4.90a	4.98a	3.52b	4.59a	0.13
Flavour Accept.	3.51b	4.71a	4.62a	3.61b	4.72a	0.16
Intensity	3.34b	4.82a	4.98a	3.38b	4.82a	0.12
Overall Acceptability	3.07b	4.71a	4.57a	3.12b	4.68a	0.15
Purchase Intent	2.12b	3.07a	3.21a	2.28b	3.34a	0.09

a-b, Means with different letters in the same row are significantly ($P<0.05$) different.
[x]Treatments: CON, control; SM, still marination; SMT, SM followed by tumbling; BT, blade tenderization; and BTSM, BT followed by SM.
[y]Attributes (appearance, tenderness, flavour, juiciness and overall acceptability) were evaluated based on a 6-point scale, where 1 = dislike very much and 6 = like very much. Intensity of tenderness, flavour and juiciness was evaluated based on a 6-point descriptive scale (*i.e.*, for tenderness, 1 = very tough and 6 = very tender; for flavour, 1 = very bland and 6 = very intense; and for juiciness, 1 = very dry and 6 = very juicy). Purchase intent for the steaks was evaluated based on a 4-point scale, where 1 = definitely not and 4 = definitely yes.
[z]S.E.M, Standard error of the mean.

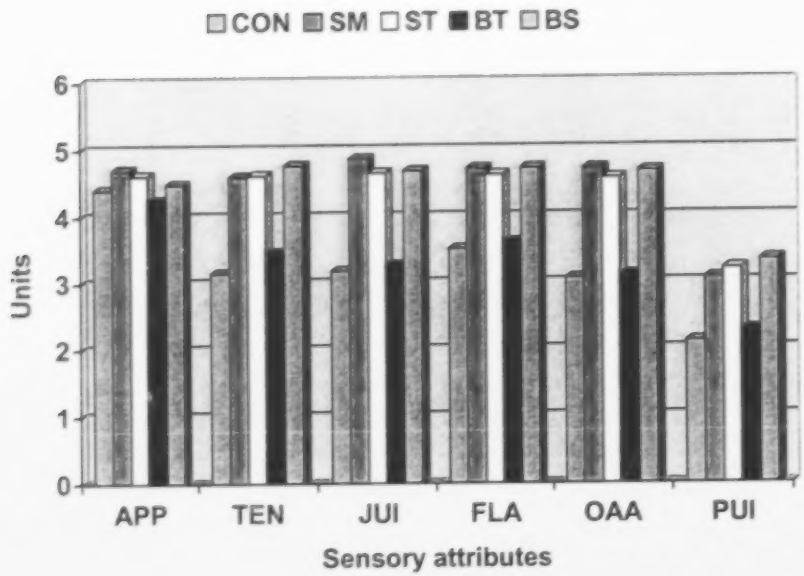


Figure 4.4. Effect of treatment on sensory attributes of bison *biceps femoris* steaks. Treatments: CON, control; SM, still marination; SMT, SM followed by tumbling; BT, blade tenderization; and BTSM, BT followed by SM. Attributes (APP, appearance; TEN, tenderness; FLA, flavour; JUI, juiciness; and OAA, overall acceptability) were evaluated based on a 6-point scale, where 1 = dislike very much and 6 = like very much. PUI, Purchase intent for the steaks was evaluated based on a 4-point scale, where 1 = definitely not and 4 = definitely yes.

Summary of recommendations to the bison meat industry based on the present findings from this study and proposed future research

Recommendations to the industry:

Based on the findings from this research project, recommendations to the bison meat industry are as follows:

- Bison meat is very different from that of beef in terms of the period necessary for ageing the meat, and how it should be chilled after slaughter. For beef, it generally takes ~ 14-21 days of ageing/conditioning to achieve a desirable texture, but this standard ageing protocol **does not** apply to bison meat, thus indicating that biochemical and physico-chemical characteristics of bison meat are different in some respects from that of beef.

- Ageing can significantly improve the tenderness of bison meat; however, a minimum of a 3 weeks' period was necessary to see a marked improvement (*NB*, from the data collected it can be hypothesized that an even longer ageing period will be desirable for bison meat tenderization).

- Data from profiling of specific bison muscles can offer insight in to how these muscles might behave in a value-added product.

- Marination or moisture-enhancement has a great deal of potential in improving the texture of bison meat. Processors could successfully employ enhancement to produce value-added meat products from lesser-values cuts of bison; opportunities can further be widened by using combinations of different herbs, spices and flavours in the marinade solutions. Small processors who cannot afford mechanical injectors and have small volume of meat to process can successfully use still marination.

Proposed future research:

From the results obtained for this project, it is clear that ageing and marination have positive effects on the palatability of lesser-value cuts; however, it took a long time to age bison meat to achieve a significant improvement in tenderness. Strategies are therefore needed to minimize the ageing period and to make meat more tender in the process. Inconsistency in quality and the amount of variation in tenderness of bison meat are some of factors responsible for its lack of acceptance by the consumers. To decrease this inconsistency a different approach of post-mortem intervention (*e.g.*, manipulation of the proteolytic activities) may be warranted to increase the consistency in the quality of bison meat cuts, especially of the lesser-value cuts.

PERSONNEL FUNDED BY THE PROJECT

(for the period August 1, 2003 to October 31, 2005)

Dr. Jagvinder Dhanda	Meat Scientist	26 person months

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Saskatchewan Agriculture and Food

Dr. Kofi Agblor
Ms. Dawn Loveday

Alberta Food Processing Development Centre

Ms. Sandra Perrin

Respondent #_____

Date_____

CODE:

BISON STEAK

Take a bite of cracker and a drink of water before you start.

Please look at and taste the product presented and indicate how much you liked/disliked it, considering all characteristics (Appearance, Tenderness, Juiciness and Flavour).

APPEARANCE OF MEAT

☐	☐	☐	☐	☐	☐
Dislike Very Much	Dislike Moderately	Dislike Slightly	Like Slightly	Like Moderately	Like Very Much

MEAT TENDERNESS

☐	☐	☐	☐	☐	☐
Dislike Very Much	Dislike Moderately	Dislike Slightly	Like Slightly	Like Moderately	Like Very Much

HOW TENDER IS THE MEAT?

☐	☐	☐	☐	☐	☐
Dislike Very Much	Dislike Moderately	Dislike Slightly	Like Slightly	Like Moderately	Like Very Much

JUICINESS

☐	☐	☐	☐	☐	☐
Dislike Very Much	Dislike Moderately	Dislike Slightly	Like Slightly	Like Moderately	Like Very Much

HOW JUICY IS THE MEAT?

☐	☐	☐	☐	☐	☐
Dislike Very Much	Dislike Moderately	Dislike Slightly	Like Slightly	Like Moderately	Like Very Much

Respondent #_____

Code: _____

FLAVOUR OF MEAT

☐	☐	☐	☐	☐	☐
Dislike Very Much	Dislike Moderately	Dislike Slightly	Like Slightly	Like Moderately	Like Very Much

HOW INTENSE IS THE FLAVOUR?

☐	☐	☐	☐	☐	☐
Very Bland	Moderately Bland	Slightly Bland	Slightly Intense	Moderately Intense	Very Intense

OVERALL ACCEPTABILITY

☐	☐	☐	☐	☐	☐
Dislike Very Much	Dislike Moderately	Dislike Slightly	Like Slightly	Like Moderately	Like Very Much

WOULD YOU BUY IT?

☐	☐	☐	☐
Definitely	Probably	Probably **NOT**	Definitely **NOT**

GENDER: **Male** ☐ **Female** ☐

AGE:

☐	☐	☐	☐	☐
18- 25 years	25-34 years	35-44 years	45-54 years	55-65 years

COMMENTS: Your comments about the sample are welcome and would be very helpful. (Use back page if needed).

Thank you.